DOCUMENT RESUME

ED 175 720 SE 028 761

AUTHOR Wheatley, Grayson H.; Shumway, Richard J.
TITLE Impact of Calculators in Elementary School Mathematics. Final Report.
INSTITUTION Purdue Univ., Lafayette, Ind. Dept. of Education.; Purdue Univ., Lafayette, Ind. Dept. of Mathematics.
SPONS AGENCY National Science Foundation, Washington, D.C.
PUB DATE Jul 79
GRANT NSF-SED-77-18077
NOTE 121p.; Contains light and broken type in Appendices

EDRS PRICE MF01/PC05 Plus Postage.
DESCRIPTORS Attitudes; *Calculation; Concept Formation; Educational Change; Effective Teaching; Elementary Education; Elementary School Mathematics; *Learning Activities; *Mathematics Curriculum; *Mathematics Education; *Mathematics Instruction; *Research
IDENTIFIERS *Calculators

ABSTRACT

Widespread concern over the use of calculators by young children prompted a broad year-long study of the impact of calculators on elementary school mathematics learning. Two teachers from each of grades 2-6 from five midwestern states participated in the study, which was designed to approximate a "first use" level of calculators in schools. Pupils continued to study from their regular mathematics textbooks and teachers were encouraged to select calculator activities from reference materials made available by the study. The experimenters made no attempt to prescribe calculator activities or a specific frequency of calculator use. The following conclusions seem warranted: (1) there are no measurable detrimental effects for the first-year use of calculators for teaching mathematics in grades 2-6; (2) children have a high, positive attitude toward using calculators in mathematics; and (3) children learn to use calculators for computation with 30 minutes of instruction and can perform computations much more successfully than children not using calculators. Informal observations by site directors and teachers suggest that curriculum implications for calculators in the elementary school could be dramatic. The authors recommend further research on the effects of longer and more intensive calculator use. (Author/MP)

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IMPACT OF CALCULATORS IN ELEMENTARY SCHOOL MATHEMATICS

FINAL REPORT
July 1979

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Grant No. SED77-18077

Research in Science Education
National Science Foundation

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Rationals

With the widespread availability of inexpensive calculators, educators and parents have expressed concern over the effects of calculator use on basic mathematical skills. Public debate over calculator use in teaching mathematics is most spirited and appears most controversial at the elementary school level (Shumway, 1976). While some argue that calculator use will result in loss of thinking skills and knowledge of basic facts, others cite increased motivation and better understanding as a potential benefits of calculator use. As the result of the many unanswered questions about calculator use effects, many professional groups have released position statements calling for experimentation with the use of calculators in classrooms. (NCTM, 1974; Higgins, 1974; NACOME, 1975; RAC, 1976; NIE-NSF, 1977).

The Calculator Information Center has made a conserted effort to collect and abstract research reports dealing with calculator effects. In a recent report (Suydam, 1979), 44 studies were summarized and critiqued. A careful reading of these reports suggests that many questions remain unanswered. Most of the studies reported suffered from such serious design and sample problems that few valid conclusions could be gleaned from them.

The factors contributing to the need for a careful study of calculator impact in elementary school mathematics include:

1. Calculators are readily available,
2. The public has expressed great concern about debilitating effects, and
3. Adequate research regarding the effects of calculator use is not available.

Based on these factors, a year-long study of the impact of calculators on basic number facts, mathematics concepts, computations, applications, new topics, and attitudes was conceived. The purpose was to determine the impact of calculator use for teaching elementary school mathematics (grades 2-6) on the achievement and attitudes of students.

Five sites were identified so that:

1. data could be gathered quickly and efficiently,
2. stability of results could be established by replication, and
3. generalizability of the findings would be maximized.

Method

Sample

The sampling concerns include three major levels:

1. location of research sites and identification of directors,

2. selection of representative schools, and

3. identification and selection of participating teachers and classes.

The five sites are from five midwestern states and located within 300 miles of the project coordination site. The site directors are all mathematics educators with a history of mathematics education research productivity.

The schools were selected by the site directors from schools in the area surrounding their location. The selection of schools at the sites was coordinated so as to have a variety of attendance area communities represented. The schools selected represent a broad spectrum from large urban schools, to suburban schools, to rural consolidated attendance area schools.

Classes and teachers were selected by each of the five site directors through a voluntary cooperative effort. Two teachers and their classes were selected at each grade level 2-6 at each site. In small schools, nearly all teachers and classes at grades 2-6 participated; in larger schools teachers were selected through cooperative discussions by teachers, principal, and researcher. Table 1 and Table 2 summarize school characteristics by site. Note the broad range of school types from rural to large city urban. Standardized testing in October indicated mathematics achievement levels ranging from nearly two

Table 1

Site Characteristics: Descriptive Statistics

Characteristic	Site				
	1	2	3[a]	4	5
Number of Students in Building	780	348	620 (K-3) 550 (4-6)	745	420
Attendance Rate (Percent)	97	96	92 (K-3) 93 (4-6)	96	95
Average Class Size (2-6)	27.2	23.2	28.7	25.3	25.5
Percent Minority	0	6	50	6	2
Percent Bussed	100	19	45	50	18
County Population (1970)	109,378	72,127	907,872	80,911	833,249
School Type	Rural	Small City	Large Urban	Small City Suburban	Large City Suburban
Income Level	Low-Middle	Middle	Low	High	Middle
Building Constructed	1968	1954,1963	1957	1964	1955,1958, 1968

[a] site housed in 2 buildings K-3, 4-6.

Table 2

Site Characteristics:

Grade Equivalents for October Standardized Testing by Site

Grade Level	Test	Site 1	2	3	4	5
Grade [a] 2	Concepts	2.1	2.7	2.0	2.8	2.7
	Computations	2.1	2.4	2.0	2.7	2.6
	Application	1.9	2.6	2.1	2.9	2.9
Grade 3	Concepts	3.0	3.7	2.7	4.0	3.7
	Computations	2.6	3.4	2.8	3.7	3.4
	Application	2.8	3.5	2.9	3.9	3.8
Grade [b] 4	Concepts	4.3	4.8	3.3	4.7	4.8
	Computations	4.2	4.5	3.8	4.8	4.3
	Application	4.2	5.0	3.7	4.5	4.9
Grade 5	Concepts	4.9	6.1	4.2	6.4	5.3
	Computations	5.4	5.7	4.6	6.5	5.7
	Application	4.7	5.8	4.0	6.0	5.4
Grade 6	Concepts	6.1	6.5	4.5	7.5	6.5
	Computations	6.0	6.8	5.1	7.4	6.4
	Application	5.4	6.7	4.3	7.1	6.3

[a] Grades 2-3 Stanford Mathematics Achievement Primary IIA

[b] Grades 4-6 Stanford Mathematics Achievement Intermediate IA

grade levels below norm to more than one grade level above norm.

At each grade level at each site, teachers and their classes were randomly assigned to one of two treatments (no calculator, calculator). A total of fifty classes, ten at each grade level, 2-6; and five per treatment at each grade level were identified. Table 3 shows the sampling design. For common testing purposes, the data were grouped by grades 2-3 and 4-6. Each site was responsible for 10 classes, with one class at each grade level in each treatment group.

Treatments

The basic goal was to investigate the impact of calculator use in elementary schools with generalizability of the results of critical concern. The treatments were designed to be those treatments most likely to represent the initial calculator use schools would typically consider. Teachers taught their own classes and the regular text formed the basis for the mathematics instruction. There were two treatments, a no calculator treatment and a calculator treatment. The calculator treatment consisted of the following:

1. children used simple four-function calculators
2. teachers attended two workshops on teaching with calculators, and

Table 3

Sampling Design, Primary Level

Treatments	Grades	
	Second	Third
No Calculator	5	5
Calculator	5	5

N = 20 classes

Sampling Design, Intermediate Level

Treatments	Grades		
	Fourth	Fifth	Sixth
No Calculator	5	5	5
Calculator	5	5	5

N = 30 classes

3. single reference copies of available supplementary classroom materials were availabe at each school.

Pupils continued to study from their regular textbook. Four different series were used at the five sites. Teachers were encouraged to select calculator activities from reference materials made available and to use calculators with their mathematics classes. Teachers were encouraged not to have pupils check answers with a calculator. The experimenters made no attempt to prescribe calculator activities or a specific level of calculator use, e.g., daily. This study was designed to approximate a "first use" level of calculators in schools. Almost no calculator use existed prior to study.

Initially, all teachers utilized some form of introductory calculator activity with their classes. In most cases this was based on ideas suggested in the workshop and included:

1. performing straightforward computations on the calculator,
2. exploring the calculator features, e.g., overload signal, constant addend, decimal representation,
3. counting on a calculator using the constant addend, and
4. instructional games.

The extent of calculator use varied widely among the twenty-five teachers in the calculator group. While some teachers rarely used calculators (less than 10% of the time), others made extensive, regular use of calculators in mathematics instruction (more than 90% of the time). On the average, calculators were used 30 to 40% of the time. Teachers generally did unit testing without calculators. Some teachers made extensive use of the reference materials. For example, two teachers prepared a calculator workbook (a collection of calculator activities) which supplemented the ongoing mathematics instruction. These same teachers utilized calculators in teaching daily topics. Other teachers allowed free use of calculators.

Several teachers were observed using calculators in the introduction of multiplication. Using the constant addend function, pupils counted by twos, fives or sevens in building the concept of multiplication as repeated addition. Primary grade teachers used the calculators in renaming numbers, building place value ideas, and stressing counting activities. Intermediate grade teachers used calculators in studying primes, introducing decimals, building estimations skills, and in working application problems. A variety of other uses were observed.

The extent of calculator use seemed to be determined

by several factors. Teachers that were confident with mathematics tended to make more use of calculators. Some teachers may have resisted the use of calculators because of their educational philosophies, although most teachers seem favorable to the use of calculators. No differences were noted between the entent of calculator use between primary and intermediate grades.

Sample calculator activities

1. Counting (primary). "Enter 1 ⊠ 1 = . Continue pressing ⊟ until you reach 1000." Through this activity, pupils gain an intuitive feeling for large numbers.

2. The game of wipe-out (primary). To wipe out a digit in a multidigit representation, the child subtracts the appropriate number to show a zero in that place. This game develops knowledge of place value concepts.

3. Estimation (primary or intermediate). "Enter 241, + . Now find a number added to 241 which gives a sum in the range shown."

4. Testing for primes (Intermediate) "Determine whether 183 is prime or composite." The calculator is used to test for divisibility by 2,3,5,7,11, and 13.

5. Applications (Intermediate) "Find the change from $20.00 if you buy items costing $2.37,$3.45, and $7.06."

Site directors and their research assistants attempted to play the role of mathematics consultant for all teachers in both treatments. Classes were observed almost daily and frequent conservations about problems of teaching mathematics were held. Every effort was made by researchers to equalize their impact across both treatments and sites. The role of a mathematics consultant for the overall mathematics program was the role the researcher adopted. Classroom-teacher was the experimental unit and these units were randomly assigned to treatment groups. The teacher effects were randomly distributed across treatment groups so teachers were expected to make their own decisions about instruction during the experiment.

In order to test calculator impact and at the same time provide recovery time if debilitating effects were found, a two phase treatment plan was used. After 15 weeks of instruction and subsequent testing, the calculators were moved from calculator classes to no calculator classes and a revised calculator treatment involving more researcher intervention was conducted. The second phase treatments were 9 weeks in duration. The calculators

used in both phases were simple four-function calculators with a change sign key (Texas Instruments, TI-1000). Each student was provided a calculator, on which they taped their name, during their calculator phase. Table 4 gives the actual treatment days and Table 5 gives the battery and calculator consumption data by site.

The testing was designed to detect possible debilitating effects for calculator use on general mathematical abilities. Attitudes, estimation skills, and knowledge of special topics were also measured to detect possible gains for calculator use. The tests administered at each test period are shown in Table 6.

The Attitude tests (MATT, CATT) were 6-item semantic differential instruments designed by the researchers. Copies of the tests are included in Appendix A. The four basic facts tests (ADD, SUB, MUL, DIV) each consisted of 20 randomly selected items (10 easy and 10 hard basic fact combinations). These were read to students with a 5 second delay between items for responding. A copy of these tests are included in Appendix A. The estimation test (EST) was a 12-item test designed by the researchers to be read with a 5 second delay between items for responding. A copy of the test is included in Appendix A. The same tests for attitude, basic facts, and estimation were used at all grade levels, 2-6. Two forms of a

Table 4

Days of Treatments by Site

	Site					
	1	2	3	4	5	Mean
Snow Days (No School)	18	2	3	6	7	7.2
Treatment Days:						
Phase I	56	72	68	74	63	66.6
Phase II	32	50	42	39	45	41.6

Table 5

Calculator and Battery Replacement

Counts by Site

	Site					
	1	2	3	4	5	Mean
Batteries Opened	460	570	620	400	480	506
Calculators	180	180	180	180	210	186
Percent of Calculators Replaced	4.4	8.9	8.3	8.3	9.0	7.8

Table 6

Tests Administered at each of the test periods.

	Grades	Tests		
		Pre	Mid	Post
Mathematics Attitude (MATT)	2-6	x	x	x
Calculator Attitude (CATT)	2-6	x	x	x
Addition Facts Test (ADD)	2-6	x	x	x
Subtraction Facts Test (SUB)	2-6	x	x	x
Multiplication Facts Test (MUL)	2-6	x	x	x
Division Facts Test (DIV)	2-6	x	x	x
SAT Concepts, Primary II(CONC-P)	2-3	x		
SAT Concepts, Primary III(CONC-P)	2-3		x	
SAT Computations, Primary II(COMP-P)	2-3	x		
SAT Computations, Primary III(COMP-P)	2-3		x	x
SAT Applications, Primary II(APPL-P)	2-3	x		
SAT Applications, Primary III(APPL-P)	2-3		x	
SAT Concepts, Intermediate I(CONC-I)	4-6	x		
SAT Concepts, Intermediate II(CONC-I)	4-6		x	
SAT Computations, Intermediate I(COMP-I)[a]	4-6	x		
SAT Computations, Intermediate II(COMP-I)	4-6		x	x
SAT Applications, Intermediate I (APPL-I)	4-6	x		
SAT Applications, Intermediate II(APPL-I)	4-6		x	
SAT Computations, Advanced (COMP-A)[b]	4-6		x	

Table 6 (Continued)

Estimation Test (EST)[c]	x	x
Special Topics Test,Primary (SPEC-P)[c]	x	x
Special Topics Test, Intermediate (SPEC-I)[c]	x	x

---

[a]Also administered to grades 2 and 3 with calculators.

[b]Administered to grades 4,5 and 6 with calculators.

[c]Revised for posttest administration

researcher designed special topics tests (SPEC) were used in the February testing, a primary level form of 18 items and an intermediate level form of 23 items. Revised versions of 22 items and 35 items were used in the May testing. The special topics test consisted of two parts, one to be completed without a calculator and the other with a calculator. Items selected for the special topics test involved negative integers, decimals and large numbers. These items were chosen because the researchers felt calculator experienced children would have an advantage on such items. Copies of these tests are included in Appendix A.

The Mathematics Tests of the Stanford Achievement Tests (1972, 1973) were used to test concepts (CONC), Computations (COMP), and Applications (APPL). A summary of the Stanford Achievement Test schedule follows:

Time	Grade Level	Test	Conditions
October	2-3	Primary Level IIA Concepts, Computations, and Applications	No Calculator
October	4-6	Intermediate Level IA Concepts, Computations, and Applications	No calculator
February	2-3	Primary Level IIIA Concepts, Computations, and Applications	No calculator
February	2-3	Intermediate Level IA Computations (only)	Calculator

Time	Grade Level	Test	Conditions
February	4-6	Intermediate Level IIA Concepts, Computations, and Applications	No calculator
February	4-6	Advanced Level Computations (only)	Calculator
May	2-3	Primary Level IIIA Computations (only)	No calculator
May	4-6	Intermediate Level IIA Computations (only)	No calculator

Note that computation tests to be taken with calculators allowed were administered at each grade level.

Table 7 shows the Cronbach's alpha internal consistency reliability estimates for the tests administered. Estimates were generally above .8. Estimates lower than .8 were accounted for by the test either being too easy (for example, addition facts in grade 6) or too difficult (estimation or division facts in grade 2) and consequently reflected either students responding randomly because questions were too difficult or no student errors other than careless ones.

Since teachers were part of the classroom-teacher experimental unit, preliminary descriptive data on teacher characteristics was gathered with a researcher designed instrument in October. These data are summarized in Table 8.

In addition to regular monitoring of all classrooms, formal observation of the complete mathematics lessons for

Table 7

Test Reliability Estimates

	Reliability Estimates[a]
Mathematics Attitude	.82 - .92
Calculator Attitude	.66 - .88
Addition Facts	.55 - .89
Subtraction Facts	.88 - .90
Multiplication Facts	.84 - .94
Division Facts	.75 - .95
Concepts	.76 - .89
Computations	.72 - .93
Applications	.78 - .93
Estimation	.29 - .68
Estimation (revised)	.39 - .71
Special Topics	.59 - .90
Special Topics (revised)	.77 - .92
Computation with Calculators	.60 - .88

[a] Cronbach's Alpha internal consistency

Table 8

Teacher Characteristics by Site

Characteristic	Site 1	2	3	4	5
Number	10	10	10	10	10
Average Age	36-40	36-40	41-45	26-30	41-45
Female/Male	8/2	9/1	10/0	9/1	9/1
Average Years Teaching	8-11	8-11	12-15	4-7	8-11
Average College Credits in Mathematics	8-11	8-11	4-7	8-11	4-7
Have Calculators at Home	10	9	8	10	9
Average Personal Use of Calculator	Occasionally	Occasionally	Seldom	Occasionally	Occasionally

all teachers was made every 11 days during Phase I. In order to insure comparability across all sites, each site and every classroom was visited by the evaluator and/or co-directors in November and January. The site visits detected a high degree in similarity of treatment conditions among the sites. The teachers at the sites ranged in age from 22 to 63 with the average age around 40. Ninety percent of the teachers were female with an average of 8-9 years of experience. These teachers averaged from 6-8 college credits in mathematics and had calculators at home which they did not use more than occasionally.

Statistical Analysis

The basic design for the research was as follows:

R_1: O_1 X_1 O_2 X_3 O_3

R_2: O_1 X_2 O_2 X_4 O_3

R_1 = Treatment Group One

R_2 = Treatment Group Two

O_1 = Pretests (October 3-6,1977)

O_2 = Midtests (February 13-17, 1978)

O_3 = Posttests (May 1-3, 1978)

X_1 = No Calculator Use (October 10-February 10)

X_2 = Calculator Use (October 10-February 10)

X_3 = Modified Calculator Use (February 17-April 28)

X_4 = Modified No Calculator Use (February 17-April 28)

The pretests were used to check comparability of groups, the midtests were used to detect the effects for the phase I treatments, and the posttests were used to detect the cumulative effects of the phase I and phase II treatments. The primary statistical analysis was a two factor fixed effects multivariate analysis of variance. The analysis design matrix is given in Table 3. Since the major concern was for debilitation or a lack of debilitation, the power of the statistical tests were computed for all the univariate significance tests relative to treatment effects.

For the principal analyses the independent variables were:

1. Treatment (2 levels: no calculator or calculator).
2. Grade (2 levels in one analysis: Grades 2, 3; and 3 levels in the other analysis: Grades 4, 5, 6).

The potential pretest covariates were:

1. Mathematics Attitude (MATT)
2. Calculator Attitude (CATT)
3. Addition Facts (ADD)
4. Subtraction Facts (SUB)
5. Multiplication Facts (MUL)
6. Division Facts (DIV)
7. Mathematics Concepts (CONC)
8. Computations (COMP)
9. Mathematics Applications (APPL)

The multivariate analyses groupings were variables 1 and 2 together, variables 3, 4, 5, and 6 together, and variables 7,8, and 9 together.

The midtest dependent variables were:

1. Mathematics Attitude (MATT)
2. Calculator Attitude (CATT)
3. Addition Facts (ADD)
4. Subtraction Facts (SUB)
5. Multiplication Facts (MUL)
6. Division Facts (DIV)
7. Mathematics Concepts (CONC)
8. Computations (COMP)
9. Mathematics Applications (APPL)
10. Estimation (EST)
11. Special Topics (SPEC)
12. Computations with Calculators (COMP/CALC)

The multivariate midtest analyses groupings were variables 1 and 2 together, variables 3, 4, 5, and 6 together, variables 7, 8, and 9 together, and variables 10, 11, and 12 together.

The posttest dependent variables were:

1. Mathematics Attitude (MATT)
2. Calculator Attitude (CATT)
3. Addition Facts (ADD)
4. Subtraction Facts (SUB)
5. Multiplication Facts (MUL)
6. Division Facts (DIV)
7. Computations (COMP)
8. Estimation (EST)
9. Special Topics (SPEC)

The multivariate posttest analyses groupings were variables 1 and 2 together, variables, 3, 4, 5, and 6 together, variable 7 alone, and variables 8 and 9 together.

Secondary analyses included summary statistics for student and teacher background characteristics and for observational data taken during the experiment.

Results

Pretest

The purpose of the pretest analysis was to identify the level of achievement and attitudes of students prior to treatments and determine whether or not pretest differences would require covariance procedures in subsequent analyses. The pretests were given October 3-6, 1977. Table 9 and Table 10 give the means and standard deviations for each cell on the pretest measures. Tables 11 and 12 give the multivariate and univariate analyses of variance for the pretest measures. Tables 13 and 14 give margin means for Grade and Treatment contrasts and summarize the multivariate and univariate analyses of variance for the pretest measures. Since no interaction effects were significant, the interaction contrast was omitted from the summary tables. In the Primary grades (2-3) the expected grade level differences were found on basic facts and mathematics achievement while there were no differences found by grade on attitudes. The treatment groups were assumed to be equivalent since no evidence of treatment group differences was found before the experiment. Due to the apparent equivalence of the treatment groups no covariance procedures were used in subsequent analyses.

Table 9

Pretest Means and Standard Deviations
for Grades 2-3 by treatment group (n_i=5)

Treatment	Statistic	Variables			
Attitude Variables		Mathematics Attitude (MATT)			Calculator Attitude (CATT)
2NC	M	23.7			27.1
	SD	1.3			2.0
3NC	M	21.3			28.1
	SD	2.7			0.9
2C	M	22.2			28.1
	SD	2.5			1.1
3C	M	23.4			27.9
	SD	3.4			1.2
Basic Facts		ADD	SUB	MUL	DIV
2NC	M	13.9	11.3	3.3	1.3
	SD	2.7	3.1	1.8	0.9
3NC	M	18.9	16.1	6.1	4.0
	SD	0.5	1.8	3.4	3.6
2C	M	15.3	13.1	1.9	0.7
	SD	2.7	3.1	1.8	0.7
3C	M	18.3	16.4	7.2	5.5
	SD	2.1	2.7	5.0	6.4
Mathematics Achievement		Concepts (CONC)	Computations (COMP)		Applications (APPI)
2NC	M	17.3	18.3		14.2
	SD	3.1	2.1		2.0
3NC	M	26.0	24.9		18.8
	SD	2.1	3.2		1.4
2C	M	19.3	18.4		14.9
	SD	4.2	4.2		3.9
3C	M	25.3	25.8		20.3
	SD	3.9	4.5		3.0

2NC - Grade 2, No Calculator; 3C - Grade 3 Calculator; M - Mean;
SD - Standard Deviation

Table 10

Pretest Means and Standard Deviations
for Grades 4-6 by Treatment Group (n_1=5)

Treatment	Statistic	Variables			
Attitude Variables		Mathematics Attitude			Calculator Attitude
4NC	M	20.6			27.6
	SD	3.0			1.4
5NC	M	21.3			27.3
	SD	2.3			0.9
6NC	M	21.5			26.7
	SD	1.9			0.5
4C	M	21.8			27.3
	SD	1.4			1.0
5C	M	20.5			28.0
	SD	2.2			0.5
6C	M	21.6			26.2
	SD	1.3			1.4
Basic Facts		ADD	SUB	MUL	DIV
4NC	M	19.4	18.5	13.9	11.0
	SD	0.5	0.9	3.2	3.7
5NC	M	19.7	18.3	18.0	14.4
	SD	0.3	1.7	2.0	4.3
6NC	M	19.1	18.1	18.0	16.0
	SD	1.6	2.5	2.9	4.3
4C	M	19.2	18.0	12.8	8.9
	SD	0.5	1.4	2.8	3.2
5C	M	19.5	18.5	18.1	15.0
	SD	0.5	0.8	1.2	2.5
6C	M	19.5	18.7	19.0	16.9
	SD	0.6	1.6	1.4	3.4

Table 10 (Continued)

Mathematics Achievement		Concepts (CONC)	Computations (COMP)	Applications (APPL)
4NC	M	15.1	15.9	24.2
	SD	3.5	3.5	4.8
5NC	M	18.5	23.7	28.2
	SD	5.2	6.8	6.1
6NC	M	21.4	28.3	30.1
	SD	4.8	5.8	5.6
4C	M	12.6	15.0	22.0
	SD	3.0	1.4	4.8
5C	M	18.4	24.1	26.8
	SD	3.1	3.4	3.9
6C	M	21.8	28.8	31.6
	SD	4.3	5.9	5.1

4NC - Grade 4, No Calculator; 6C - Grade 6, Calculator; M - Mean;
SD - Standard Deviation

Table 11

Multivariate and Univariate Analyses of Variance

for Group Equivalence on Pretests

Grades 2-3

Variable(s)	Test	Source	df	F	p<
MATT, CATT	M	TxG	2,15	1.607	.233
MATT	U		1,16	2.309	.148
CATT	U		1,16	0.943	.346
MATT, CATT	M	Grade	2,15	0.330	.724
MATT	U		1,16	0.213	.651
CATT	U		1,16	0.456	.509
MATT, CATT	M	Treatment	2,15	0.216	.808
MATT	U		1,16	0.066	.801
CATT	U		1,16	0.412	.530
ADD,SUB,MUL,DIV	M	TxG	4,13	0.602	.668
ADD	U		1,16	1.015	.329
SUB	U		1,16	0.370	.552
MUL	U		1,16	0.671	.425
DIV	U		1,16	0.436	.519
ADD,SUB,MUL,DIV	M	Grade	4,13	4.079	.023*
ADD	U		1,16	16.651	.001**
SUB	U		1,16	11.017	.004**
MUL	U		1,16	7.759	.013*
DIV	U		1,16	5.048	.039*
ADD,SUB,MUL,DIV	M	Treatment	4,13	0.667	.626
ADD	U		1,16	0.127	.726
SUB	U		1,16	0.675	.423
MUL	U		1,16	0.012	.914
DIV	U		1,16	0.081	.780
CONC ,COMP ,APPI	M	TxG	3,14	2.209	.132
CONC	U		1,16	0.780	.390
COMP	U		1,16	0.064	.804
APPI	U		1,16	0.106	.749

Table 11(Continued)

CONC ,COMP ,APPL	M	Grade	3,14	6.935	.004**
CONC	U		1,16	22.767	.001**
COMP	U		1,16	18.630	.001**
APPL	U		1,16	16.639	.001**
CONC ,COMP ,APPL	M	Treatment	3,14	0.473	.706
CONC	U		1,16	0.152	.702
COMP	U		1,16	0.115	.739
APPL	U		1,16	0.742	.402

*p <.05
**p <.01

M - Multivariate
U - Univariate

Table 12

Multivariate and Univariate Analyses of Variance

for Group Equivalence on Pretests

Grades 4-6

Variable(s)	Test	Source	df	F	p<
MATT, CATT	M	TxG	4,46	0.588	.673
MATT	U		2,24	0.592	.561
CATT	U		2,24	0.875	.430
MATT, CATT	M	Grade	4,46	1.802	.145
MATT	U		2,24	0.260	.773
CATT	U		2,24	3.823	.036*
MATT, CATT	M	Treatment	2,23	0.036	.965
MATT	U		1,24	0.074	.788
CATT	U		1,24	0.012	.915
ADD,SUB,MUL,DIV	M	TxG	8,42	0.336	.947
ADD	U		2,24	0.502	.612
SUB	U		2,24	0.325	.726
MUL	U		2,24	0.493	.617
DIV	U		2,24	0.539	.590
ADD,SUB,MUL,DIV	M	Grade	8,42	4.191	.001**
ADD	U		2,24	0.488	.621
SUB	U		2,24	0.026	.974
MUL	U		2,24	14.808	.001**
DIV	U		2,24	8.688	.001**
ADD,SUB,MUL,DIV	M	Treatment	4,21	0.037	.997
ADD	U		1,24	0.005	.944
SUB	U		1,24	0.009	.927
MUL	U		1,24	0.000	1.000
DIV	U		1,24	0.014	.908
CONC ,COMP ,APPL	M	TxG	6,44	0.829	.554
CONC	U		2,24	0.377	.690
COMP	U		2,24	0.062	.940
APPL	U		2,24	0.367	.697

Table 12 (Continued)

CONC1,COMP1,APPL	M	Grade	6,44	6.349	.001**
CONC	U		2,24	9.142	.001**
COMP	U		2,24	19.001	.001**
APPL	U		2,24	5.750	.009**
CONC1,COMP1,APPL	M	Treatment	3,22	0.519	.673
CONC	U		1,24	0.235	.632
COMP	U		1,24	0.000	.991
APPL	U		1,24	0.128	.724

M - Multivariate, U - Univariate

*p <.05
**p <.01

Table 13

Margin Means and Significance Levels

for Grade Level and "Treatment" Contrasts for Pretests

Grades 2-3

	Grade Level		Test		"Treatment"		Test	
			U	M			U	M
	2	3	p<	p<	NC	C	p<	p<
Attitude				.330				.808
MATT	22.9	22.4	.213		22.5	22.8	.801	
CATT	27.6	28.0	.456		27.6	28.0	.530	
Basic Facts				.023*				.626
ADD	14.6	18.6	.001**		16.4	16.8	.726	
SUB	12.2	16.2	.004**		13.7	14.7	.423	
MUL	2.6	6.7	.013*		4.7	4.5	.914	
DIV	1.0	4.7	.034*		2.7	3.1	.780	
Mathematics Achievement				.004**				.706
CONC	18.3	25.6	.001**		21.7	22.3	.702	
COMP	18.3	25.3	.001**		21.6	22.1	.736	
APPL	14.5	19.6	.001**		16.5	17.6	.402	

*p < .05, NC - no calculator, C - calculator,

**p < .01, U - Univariate, M - multivariate

Table 14

Margin Means and Significance Levels

for Grade Level and "Treatment" Contrasts for Pretest

Grades 4-6

	Grade Level			Test		"Treatment"		Test	
				U	M			U	M
	4	5	6	p<	p<	NC	C	p<	p<
Attitude					.145				.965
MATT	21.2	20.9	21.6	.773		21.1	21.3	.788	
CATT	27.5	27.6	26.5	.036(*)		27.2	27.2	.915	
Basic Facts					.001**				.997
ADD	19.3	19.6	19.3	.621		19.4	19.4	.944	
SUB	18.2	18.4	18.4	.974		18.3	18.4	.927	
MUL	13.3	18.1	18.5	.001**		16.6	16.6	1.000	
DIV	10.0	14.7	16.5	.001**		13.8	13.6	.908	
Mathematics Achievement					.001**				.673
CONC	13.9	18.4	21.6	.001**		18.3	17.6	.632	
COMP	15.4	23.9	28.6	.001**		22.7	22.6	.991	
APPL	23.1	27.5	30.9	.009**		27.5	26.8	.724	

*p < .05, NC - no calculator, C - calculator,

**p < .01, U - Univariate, M - multivariate

Midtests (Phase I)

The midtests were given February 13-17, 1978. Tables 15 and 16 give means and standard deviations for the midtests. Tables 17 and 18 give the multivariate and univariate analyses of variance tests for the midtest differences. Tables 19 and 20 summarize the margin means and the multivariate and univariate analyses for midtest differences. Since there were no interaction effects found, only the grade level and treatment contrasts are reported in the summary. Across all achievement measures, Grade 3 scores were significantly higher than Grade 2 scores ($p \leq .01$), an expected difference. There is no evidence of a treatment effect in the primary grades at even the ($p \leq .1$) level except on the special topics test where the calculator group has higher scores ($p \leq .091$). The expected grade level differences were found for grades 4-6. None of the feared debilitations were apparent.

The analysis of the observation data collected every 11 days over the 15 week duration of phase I suggest:

1. games were more prevalent in calculator classes than in no calculator classes,
2. when calculators were used by a class approximately 60% of the students were using them, and
3. calculators were used for instruction, on the average, about 40% of the class time.

Table 15

Midtest Means and Standard Deviations

for Grades 2-3 by Treatment Group (n_i=5)

Treatment	Statistic	Variables	
Attitude Variables		Mathematics Attitude (MATT)	Calculator Attitude (CATT)
2NC	M	23.0	26.6
	SD	3.3	1.1
3NC	M	21.6	27.6
	SD	1.9	1.0
2C	M	23.2	27.3
	SD	2.1	1.2
3C	M	23.3	26.8
	SD	3.0	1.3

Basic Facts		ADD	SUB	MUL	DIV
2NC	M	16.6	15.1	4.7	2.5
	SD	2.2	1.8	3.1	2.3
3NC	M	18.8	18.3	12.5	9.3
	SD	0.9	0.4	3.0	3.2
2C	M	17.8	15.0	4.0	2.5
	SD	1.0	2.2	3.6	2.9
3C	M	19.1	18.2	13.6	10.2
	SD	0.9	1.5	3.5	5.5

Mathematics Achievement		Concepts (CONC)	Computations (COMP)	Applications (APPL)
2NC	M	12.8	13.5	13.2
	SD	2.8	2.3	2.6
3NC	M	18.9	20.6	19.1
	SD	2.1	1.8	2.4
2C	M	13.8	13.0	14.5
	SD	3.8	3.9	3.5
3C	M	19.9	21.8	19.1
	SD	4.7	5.0	4.8

Table 15 (Continued)

Calculator Related Mathematics Achievement		Estimation (EST)	Special Topics (SPEC)	Computations with Calculators (COMC)
2NC	M	3.5	3.1	20.1
	SD	0.1	1.0	2.6
3NC	M	4.6	5.8	27.4
	SD	0.6	1.3	1.2
2C	M	3.6	4.0	20.4
	SD	0.6	1.2	5.1
3C	M	4.9	7.4	28.1
	SD	0.9	2.3	2.9

Table 16

Midtest Means and Standard Deviations

for Grades 4-6 by Treatment Group (n_i=5)

Treatment	Statistic	Variables	
Attitude Variables		Mathematics Attitude (MATT)	Calculator Attitude (CATT)
4NC	M	21.7	27.5
	SD	2.6	0.6
5NC	M	20.6	24.7
	SD	1.6	2.1
6NC	M	21.6	25.3
	SD	1.5	1.1
4C	M	21.7	25.7
	SD	1.7	0.9
5C	M	20.7	25.8
	SD	3.1	1.7
6C	M	21.2	24.3
	SD	1.4	1.5

Basic Facts		ADD	SUB	MUL	DIV
4NC	M	19.5	19.1	18.2	15.6
	SD	0.6	0.8	1.3	2.6
5NC	M	19.6	18.5	19.0	17.8
	SD	0.2	1.1	1.2	1.6
6NC	M	19.3	18.6	18.6	17.1
	SD	1.2	2.1	1.8	3.4
4C	M	19.2	18.4	17.2	14.5
	SD	0.5	1.1	1.7	3.5
5C	M	19.6	18.7	18.7	17.0
	SD	0.1	0.6	0.6	1.0
6C	M	19.2	18.7	19.0	17.8
	SD	0.9	1.5	1.3	2.4

Table 16 (Continued)

Mathematics Achievement		Concepts (CONC)	Computations (COMP)	Applications (APPL)
4NC	M	17.3	19.8	19.1
	SD	3.9	4.9	4.7
5NC	M	20.4	26.0	24.5
	SD	6.0	7.6	7.2
6NC	M	23.1	29.2	26.9
	SD	5.8	8.3	6.2
4C	M	15.6	16.9	17.3
	SD	3.2	2.6	3.3
5C	M	20.1	23.2	22.6
	SD	3.2	3.3	3.9
6C	M	24.0	29.6	27.7
	SD	5.0	7.3	7.4

Calculator Related Mathematics Achievement		Estimation (EST.)	Special Topics (SPEC)	Computation with Calculators (COMPC)
4NC	M	5.2	5.3	16.7
	SD	1.0	1.5	0.9
5NC	M	6.0	8.5	20.5
	SD	1.7	4.2	6.6
6NC	M	5.8	10.0	24.3
	SD	1.4	4.7	6.8
4C	M	4.6	5.1	16.4
	SD	0.5	1.4	1.5
5C	M	5.8	7.8	21.6
	SD	0.7	1.1	0.8
6C	M	6.5	11.7	24.8
	SD	1.2	4.2	4.8

Table 17

Multivariate and Univariate Analysis of Variance for Grade and Treatment Effects on Midtests for Grades 2-3

Variable(s)	Test	Source	df	F	p
MATT,CATT	M	TxG	2,15	2.262	.139
MATT	U		1,16	0.379	.547
CATT	U		1,16	2.104	.166
MATT,CATT	M	Grade	2,15	0.538	.595
MATT	U		1,16	0.300	.591
CATT	U		1,16	0.234	.635
MATT,CATT	M	Treatment	2,15	0.585	.569
MATT	U		1,16	0.615	.444
CATT	U		1,16	0.063	.805
ADD,SUB,MUL,DIV	M	TxG	4,13	0.426	.788
ADD	U		1,16	0.543	.472
SUB	U		1,16	0.000	.989
MUL	U		1,16	0.338	.569
DIV	U		1,16	0.081	.779
ADD,SUB,MUL,DIV	M	Grade	4,13	10.007	.001**
ADD	U		1,16	8.695	.009**
SUB	U		1,16	19.910	.001**
MUL	U		1,16	34.430	.001**
DIV	U		1,16	19.496	.001**
ADD,SUB,MUL,DIV	M	Treatment	4,13	0.867	.509
ADD	U		1,16	1.708	.210
SUB	U		1,16	0.023	.880
MUL	U		1,16	0.012	.915
DIV	U		1,16	0.089	.770
CONC ,COMP ,APPL	M	TxG	3,14	1.122	.374
CONC	U		1,16	0.001	.980
COMP	U		1,16	0.304	.589
APPI	U		1,16	0.176	.680

Table 17 (Continued)

CONC ,COMI ,APPI	M	Grade	3,14	9.122	.001**
CONC	U		1,16	15.132	.001**
COMP	U		1,16	26.193	.001**
APPL	U		1,16	11.587	.004**
CONC ,COMF ,APPL	M	Treatment	3,14	0.262	.850
CONC	U		1,16	0.443	.515
COMP	U		1,16	0.042	.840
APPL	U		1,16	0.187	.671
EST ,SPEC ,COMC	M	TxG	3,14	0.131	.940
EST	U		1,16	0.285	.601
SPEC	U		1,16	0.273	.609
COMC	U		1,16	0.019	.893
EST ,SPEC ,COMC	M	Grade	3,14	8.311	.002**
EST	U		1,16	17.350	.001**
SPEC	U		1,16	19.721	.001**
COMC	U		1,16	26.186	.001**
EST ,SPEC ,COMC	M	Treatment	3,14	1.498	.258
EST	U		1,16	0.456	.508
SPEC	U		1,16	3.238	.091
COMC	U		1,16	0.107	.748

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*p < .05

**p < .01

M - Multivariate

U - Univariate

Table 18

Multivariate and Univariate Analysis of Variance

for Grade and Treatment Effects on Midtests

for Grades 4-6

Variable(s)	Test	Source	df	F	p<
MATT,CATT	M	TxG	4,46	1.357	.263
MATT	U		2,24	0.035	.966
CATT	U		2,24	2.955	.071
MATT,CATT	M	Grade	4,46	2.388	.065
MATT	U		2,24	0.688	.512
CATT	U		2,24	4.595	.020(*)
MATT,CATT	M	Treatment	2,23	0.642	.536
MATT	U		1,24	0.011	.916
CATT	U		1,24	1.326	.261
ADD,SUB,MUL,DIV	M	TxG	8,42	0.399	.915
ADD	U		2,24	0.058	.944
SUB	U		2,24	0.438	.650
MUL	U		2,24	0.553	.582
DIV	U		2,24	0.375	.691
ADD,SUB,MUL,DIV	M	Grade	8,42	1.651	.140
ADD	U		2,24	0.739	.488
SUB	U		2,24	0.029	.971
MUL	U		2,24	2.295	.122
DIV	U		2,24	2.774	.082
ADD,SUB,MUL,DIV	M	Treatment	4,21	0.191	.940
ADD	U		1,24	0.255	.619
SUB	U		1,24	0.045	.834
MUL	U		1,24	0.351	.559
DIV	U		1,24	0.169	.685
CONC ,COMP ,APPL	M	TxG	6,44	0.596	.732
CONC	U		2,24	0.195	.824
COMP	U		2,24	0.227	.799
APPL	U		2,24	0.187	.830

Table 18 (Continued)

CONC ,COMP ,APPL	M	Grade	6,44	2.756	.023*
CONC	U		2,24	5.949	.008**
COMP	U		2,24	8.279	.002**
APPL	U		2,24	6.521	.005**
CONC ,COMP ,APPL	M	Treatment	3,22	1.577	.223
CONC	U		1,24	0.050	.825
COMP	U		1,24	0.653	.427
APPL	U		1,24	0.210	.651
EST ,SPEC ,COMC	M	TxG	6,44	1.431	.225
EST	U		2,24	0.777	.471
SPEC	U		2,24	0.387	.683
COMC	U		2,24	0.072	.931
EST ,SPEC ,COMC	M	Grade	6,44	3.541	.006**
EST	U		2,24	3.319	.053
SPEC	U		2,24	7.799	.002**
COMC	U		2,24	8.350	.002**
EST ,SPEC ,COMC	M	Treatment	3,22	0.278	.840
EST	U		1,24	0.036	.851
SPEC	U		1,24	0.055	.817
COMC	U		1,24	0.082	.777

*p < .05
**p < .01
M - Multivariate
U - Univariate

Table 19

Margin Means and Significance Levels for

Grade Level and Treatment Contrasts for Midtests

Grades 2-3

	Grade Level		Test		"Treatment"		Test	
	2	3	U P<	M P<	NC	C	U p<	M p<
Attitude				.595				.569
MATT	23.1	22.4	.591		22.3	23.2	.444	
CATT	27.0	27.2	.635		27.1	27.0	.805	
Basic Facts				.001**				.509
ADD	17.2	19.0	.009**		17.7	16.7	.210	
SUB	15.0	16.6	.001**		18.5	16.6	.880	
MUL	4.4	13.1	.001**		8.6	8.8	.915	
DIV	2.5	9.7	.001**		5.9	6.4	.770	
Mathematics Achievement				.001**				.850
CONC	13.3	19.4	.001**		15.8	16.9	.515	
COMP	13.3	21.2	.001**		17.1	17.4	.840	
APPL	13.8	19.1	.004**		16.1	16.8	.671	
Calculator Related Mathematics Achievement				.002**				.258
EST	3.6	4.7	.001**		4.1	4.2	.508	
SPEC	3.6	6.6	.001**		4.5	5.7	.091	
COMC	20.3	27.8	.001**		23.8	24.3	.748	

*p < .05, NC - no calculator, C - calculator

**p < .01, U - univariate, M - multivariate

Table 20

Margin Means and Significance Levels for

Grade Level and Treatment Contrasts for Midtests

Grades 4-6

	Grade Level			Test		"Treatments"		Test	
				U	M			U	M
	4	5	6	p <	p <	NC	C	p <	p <
Attitude					.065				.536
MATT	21.7	20.6	21.4	.512		21.3	21.2	.916	
CATT	26.6	25.3	24.8	.020(*)		25.8	25.3	.261	
Basic Facts					.140				.940
ADD	19.4	19.6	19.2	.488		19.5	19.3	.619	
SUB	18.7	18.6	18.7	.971		18.7	18.6	.834	
MUL	17.7	18.8	18.8	.122		18.6	18.3	.559	
DIV	15.1	17.4	17.4	.082		16.8	16.4	.685	
Mathematics Achievement					.023*				.223
CONC	16.4	20.4	23.6	.008**		20.3	19.9	.825	
COMP	18.4	24.6	29.4	.002**		25.0	23.2	.427	
APPL	18.2	23.6	27.3	.005**		23.5	22.6	.651	
Calculator Related Mathematics Achievement					.006**				.840
EST	4.9	5.9	6.2	.053		5.7	5.6	.851	
SPEC	5.2	8.1	10.8	.002**		7.9	8.2	.817	
COMC	16.5	21.0	24.6	.002**		20.5	20.9	.777	

*p < .05, NC - no calculator, C - calculator,

**p < .01, U - univariate, M - multivariate

Prior to summarizing these data the site directors were asked to make an informal estimate of the calculator use in each class at their site. The average estimate was about 30%. The apparently lower estimate of calculator use by site directors may be due to the directors' disappointment in not seeing as much use as they had hoped to see.

In order to estimate the availability of calculators to children at home, children were asked the following questions at the pre, mid and post testing times:

1. Is there a calculator in your home?
2. Are you allowed to use the calculator?
3. Do you have your own calculator?

Table 21 summarizes the results on these questions across all classes. The inference one would draw from Table 21 is that calculators are commonly available at home. Further inspection of the data shows a rather dramatic increase in the number of students who have their own calculator between the pre and mid testing times. A closer look at the data revealed that this change was no different for calculator and no calculator groups.

Posttests (Phase II)

The phase II treatments (February 17-April 28) were designed to increase the use of calculators for mathematics instruction. During this phase the calculators were

Table 21

Availability of Calculators at Home

	Grades 2-3		
	Pre	Mid	Post
Calculator at Home	83%	89%	91%
Allowed to Use	77%	80%	86%
Have Own Calculator	24%	41%	42%

	Grades 4-6		
	Pre	Mid	Post
Calculator at Home	84%	91%	91%
Allowed to Use	86%	88%	88%
Have Own Calculator	30%	46%	48%

transferred from the classes which originally had them to the classes which did not. Classroom sets of materials were provided the new calculator teachers and the site directors played a more active role. Occasionally researchers taught classes themselves or assisted classroom teachers with calculator activities. Since no differences between classes were found at midtesting, phase II could be viewed as a further test of calculator effects. Tables 22 and 23 give the cell means and standard deviations for the posttest measures. Tables 24 and 25 give the multivariate and univariate analyses of variance for the posttest measures. Since no interaction effects were found, Tables 26 and 27 report the margin means and significance levels for Grade and Treatment effects only. As in phase I, there continue to be grade level effects but no evidence of treatment effects.

One very important concern was the possibility of debilitation effects due to use of the calculator. This concern requires that attention to be directed to the power of the tests of significance for treatment effects. In this case it is important to find some indication of the possibility that significant differences that do occur will in fact be detected. Tables 28 and 29 contain the raw score differences that would have resulted in claims of significant differences ($p \leq .05$). These differences would have been detected in 95 out of 100 such studies if

Table 22

Posttest Means and Standard Deviation

for Grades 2-3 by Treatment Groups (n_i=5)

Treatment	Statistic	Variables	
Attitude Variables		Mathematics Attitude (MATT)	Calculator Attitude (CATT)
2NC	M	22.8	26.9
	SD	3.4	0.9
3NC	M	21.7	26.6
	SD	1.7	1.1
2C	M	22.4	27.6
	SD	2.6	1.5
3C	M	23.9	27.2
	SD	2.4	0.9

Basic Facts		ADD	SUB	MUL	DIV
2NC	M	17.6	16.3	7.3	5.0
	SD	1.8	1.6	4.4	3.5
3NC	M	18.9	18.9	16.6	14.0
	SD	1.3	0.6	2.8	3.1
2C	M	18.7	17.4	5.3	3.1
	SD	1.1	1.0	4.3	3.9
3C	M	19.5	18.4	17.8	15.1
	SD	0.3	1.3	1.1	2.4

Mathematics Achievement		Computations (COMP2)
2NC	M	16.9
	SD	3.0
3NC	M	24.8
	SD	2.5
2C	M	14.5
	SD	4.1
3C	M	26.1
	SD	4.0

Table 22 (Continued)

Calculator Related Mathematics Achievement		Estimation (EST)	Special Topics (SPEC)
2NC	M	3.6	7.7
	SD	0.3	2.3
3NC	M	4.6	13.0
	SD	0.7	2.2
2C	M	3.5	7.6
	SD	0.6	1.7
3C	M	5.0	13.1
	SD	1.2	2.6

Table 23

Posttest Means and Standard Deviation

for Grades 4-6 by Treatment Groups (n_i=5)

Treatment	Statistics	Variables	
Attitude Variables		Mathematics Attitude (MATT)	Calculator Attitude (CATT)
4NC	M	19.8	26.3
	SD	2.6	1.4
5NC	M	20.7	24.2
	D	2.3	2.3
6NC	M	21.2	25.1
	SD	2.4	1.2
4C	M	22.1	25.6
	SD	2.3	1.2
5C	M	20.4	25.2
	SD	4.0	2.3
6C	M	20.4	23.7
	SD	1.7	2.2

Basic Facts		ADD	SUB	MUL	DIV
4NC	M	19.8	19.1	18.7	17.0
	SD	0.3	0.4	1.0	1.3
5NC	M	19.7	19.1	19.2	17.9
	SD	0.3	0.7	0.8	1.8
6NC	M	19.5	18.8	18.9	17.4
	SD	0.5	1.8	1.6	3.6
4C	M	19.6	18.9	18.5	16.0
	SD	0.1	0.5	0.8	2.8
5C	M	19.7	19.0	19.1	17.5
	SD	0.3	0.4	0.3	0.9
6C	M	19.8	19.5	19.3	18.7
	SD	0.3	0.6	1.1	1.8

Table 23 (Continued)

Mathematics Achievement		Computations (COMP)
4NC	M	21.9
	SD	5.4
5NC	M	28.1
	SD	6.3
6NC	M	29.8
	SD	6.8
4C	M	19.6
	SD	3.4
5C	M	25.7
	SD	3.2
6C	M	32.1
	SD	6.4

Calculator Related Mathematics Achievement		Estimation (EST2)	Special Topics (SPFC2)
4NC	M	5.8	12.1
	SD	1.0	3.4
5NC	M	6.3	17.2
	SD	1.5	7.3
6NC	M	6.5	19.4
	SD	1.5	6.5
4C	M	5.0	9.9
	SD	0.6	2.9
5C	M	5.9	15.3
	SD	0.9	2.9
6C	M	6.7	21.0
	SD	1.5	6.0

Table 24

Multivariate and Univariate Analyses of Variance

for Grade and Treatment Effects on Posttests

for Grades 2-3

Variable(s)	Test	Source	df	F	p<
MATT,CATT	M	TxG	2,15	0.841	.450
MATT	U		1,16	1.310	.269
CATT	U		1,16	0.000	1.000
MATT,CATT	M	Grade	2,15	0.395	.680
MATT	U		1,16	0.033	.859
CATT	U		1,16	0.456	.509
MATT,CATT	M	Treatment	2,15	0.807	.464
MATT	U		1,16	0.535	.475
CATT	U		1,16	1.719	.208
ADD,SUB,MUL,DIV	M	TxG	4,13	0.777	.559
ADD	U		1,16	0.255	.620
SUB	U		1,16	2.215	.156
MUL	U		1,16	1.007	.330
DIV	U		1,16	1.056	.319
ADD,SUB,MUL,DIV	M	Grade	4,13	14.944	.001**
ADD	U		1,16	3.793	.069
SUB	U		1,16	11.370	.004**
MUL	U		1,16	51.039	.001**
DIV	U		1,16	51.553	.001**
ADD,SUB,MUL,DIV	M	Treatment	4,13	0.752	.574
ADD	U		1,16	2.295	.149
SUB	U		1,16	0.486	.496
MUL	U		1,16	0.072	.791
DIV	U		1,16	0.083	.777
COMP	U	TxG	1,16	1.446	.247
	U	Grade	1,16	40.830	.001**
	U	Treatment	1,16	0.128	.725

Table 24 (Continued)

EST ,SPEC	M	TxG	2,15	0.272	.765
EST	U		1,16	0.480	.498
SPEC	U		1,16	0.017	.898
EST ,SPEC	M	Grade	2,15	14.030	.001**
EST	U		1,16	14.095	.002**
SPEC	U		1,16	29.226	.001**
EST2,SPEC	M	Treatment	2,15	0.137	.873
EST	U		1,16	0.214	.650
SPEC	U		1,16	0.001	.976

*p < .05, M - multivariate, U - univariate

**p < .01

Table 25

Multivariate and Univariate Analyses of Variance

for Grade and Treatment Effects on Posttests

for Grades 4-6

Variable(s	Test	Source	df	F	p<
MATT,CATT	M	TxG	4,46	1.172	.336
MATT	U		2,24	0.947	.402
CATT	U		2,24	1.200	.319
MATT,CATT	M	Grade	4,46	0.967	.435
MATT	U		2,24	0.065	.937
CATT	U		2,24	1.974	.161
MATT,CATT	M	Treatment	4,46	0.331	.722
MATT	U		1,24	0.189	.667
CATT	U		1,24	0.288	.972
ADD,SUB,MUL,DIV	M	TxG	8,42	0.788	.616
ADD	U		2,24	1.547	.233
SUB	U		2,24	0.947	.402
MUL	U		2,24	0.311	.735
DIV	U		2,24	0.705	.504
ADD,SUB,MUL,DIV	M	Grade	8,42	0.827	.584
ADD	U		2,24	0.003	.997
SUB	U		2,24	0.065	.937
MUL	U		2,24	0.882	.427
DIV	U		2,24	1.310	.288
ADD,SUB,MUL,DIV	M	Treatment	4,21	0.166	.953
ADD	U		1,24	0.181	.674
SUB	U		1,24	0.158	.695
MUL	U		1,24	0.012	.915
DIV	U		1,24	0.003	.955
COMP	U	TxG	2,24	0.628	.542
	U	Grade	2,24	8.963	.001**
	U	Treatment	1,24	0.157	.695

Table 25 (Continued)

EST ,SPEC	M	TxG	4,46	0.271	.895
EST	U		2,24	0.372	.694
SPEC	U		2,24	0.417	.664
EST ,SPEC	M	Grade	4,46	4.809	.003**
EST	U		2,24	2.679	.089
SPEC	U		2,24	8.065	.002**
EST ,SPEC	M	Treatment	2,23	0.436	.652
EST	U		I,24	0.595	.448
SPEC	U		1,24	0.192	.665

*p < .05,
**p < .01

M - Multivariate, U - Univariate

Table 26

Margin Means and Significance Levels for

Grade Level and Treatment Contrasts for Posttests

Grades 2-3

	Grade Level		Test		"Treatments"		Test	
	2	3	U p<	M p<	NC-C	C-NC	U p<	M p<
Attitudes				.680				.464
MATT	22.6	22.8	.859		22.3	23.1	.475	
CATT	27.2	26.9	.509		26.7	27.4	.208	
Basic Facts				.001**				.574
ADD	18.1	19.2	.069		18.3	19.1	.149	
SUB	16.9	18.7	.004**		17.6	17.9	.496	
MUL	6.3	17.2	.001**		12.0	11.9	.791	
DIV	4.1	14.5	.001**		9.5	9.1	.777	
Mathematics Achievement								
COMP	15.7	25.5	.001*		20.9	20.3	.725	
Calculator Related Mathematics Achievement				.001*				.873
EST	3.5	4.8	.002**		4.1	4.3	.650	
SPEC	7.7	13.0	.001**		10.3	10.4	.976	

*p < .05 NC-C No calculator in Phase I - Calculator in Phase II

**p < .01 C-NC Calculator in Phase I - No calculator in Phase II

Table 27

Margin Means and Significance Levels for

Grade Level and Treatment Contrasts for Posttests

Grades 4-6

	Grade Levels			Test		Treatments		Test	
	4	5	6	U p<	M p<	NC-C	C-NC	U p<	M p<
Attitude					.435				.722
MATT	21.0	20.5	20.8	.937		20.6	21.0	.667	
CATT	26.0	24.7	24.4	.161		25.2	24.8	.972	
Basic Facts					.584				.953
ADD	19.7	19.7	19.7	.997		19.7	19.7	.674	
SUB	19.0	19.1	19.2	.937		19.0	19.1	.695	
MUL	18.6	19.1	19.1	.427		18.9	19.0	.915	
DIV	16.5	17.7	18.0	.288		17.4	17.4	.955	
Mathematics Achievement									
COMP	20.7	26.9	31.0	.00/**		26.5	25.8	.695	
Calculator Related Mathematics Achievement					.003**				.652
EST	5.4	6.1	6.6	.089		6.2	5.9	.448	
SPEC	11.0	16.3	20.2	.002**		16.2	15.4	.665	

*p < .05
**p < .01

NC-C - No calculator in Phase I - Calculator in Phase II

C-NC - Calculator in Phase I - No Calculator in Phase II

Table 28

Critical Treatment Differences

Required for .95 Power in Grades 2-3 (α = .05)

	Possible Raw Score Range	Pre	Mid	Post
MATT	6-30	4.47	4.53	4.44
CATT	6-30	2.32	1.97	1.92
ADD	0-20	3.75	2.28	2.12
SUB	0-20	4.65	2.76	2.03
MUL	0-20	5.58	5.58	5.84
DIV	0-20	6.31	6.28	5.57
CONC	0-35	5.88	NG	NG
CONC	0-32	NG	5.97	NG
COMP	0-37	6.20	NG	NG
COMP	0-36	NG	5.97	5.88
APPL	0-28	4.71	NG	NG
APPL	0-28	NG	5.92	NG
EST	0-12	NG	1.37	NG
EST	0-12	NG	NG	1.32
SPEC	0-18	NG	2.63	NG
SPEC	0-22	NG	NG	3.82
COMC	0-40	NG	5.61	NG

NG - Test not given

Table 29

Critical Treatment Difference Required

for .95 Power in Grades 4-6 (α = .05)

	Possible Raw Score Range	Pre	Mid	Post
MATT	6-30	3.49	3.51	4.44
CATT	6-30	1.68	2.34	3.09
ADD	0-20	1.30	1.21	0.57
SUB	0-20	2.57	2.17	1.46
MUL	0-20	—	2.33	1.68
DIV	0-20	5.96	4.33	3.88
CONC	0-32	6.83	NG	NG
CONC	0-35	NG	7.82	NG
COMP	0-40	—	NG	NG
COMP	0-45	NG	10.21	9.13
APPL	0-40	8.57	NG	NG
APPL	0-40	NG	9.50	NG
EST	0-12	NG	1.94	NG
EST	0-12	NG	NG	2.03
SPEC	0-23	NG	5.36	NG
SPEC	0-35	NG	NG	8.68
COMC	0-45	NG	7.39	NG

NG - Test not given

they were in fact true differences.

The power of this research design is compromised by the heterogeneity of the sample units across the sites. The sites varied in socioeconomic and general student ability level which increased the generalizability of the results at the expense of power.

The standard of alpha levels of .05 combined with power levels of .95 is the rigorous standard adopted. Judgements about the educational significance of the subsequent critical differences computed must be made by individual readers. While smaller critical differences might have been produced by more homogeneous sites, the differences reported in Tables 28 and 29 give an estimate of the risk involved in claiming that there were no significance differences.

Pupil Comments

At the end of the treatment, children were asked to respond to a series of questions on calculator use. Here are some non-edited quotes from children involved in the project which give some feeling and insight into how both children and adults felt about the use of calculators:

"I like the calculators. Sometimes (the teacher) lets us use them on math."

"I like the calculators cause you can play with them. and you can make proplims."

"I like them. They help me a lot. And are they smart!"

"I liked to do it a little bit. I like calculators but I hate math. I have one of my own calculators."

"it waw rille fun my Dad bote me A calculator on my Birthday it was Maysixth! it came with a booklit He side if I do the things in the booklit He Will buy me one like the Schools I rille have fun with Calculators."

"I think it would be better if we did not use the calculators."

"I like calculators i know MathBettey I like to uss calculators to Do
Math."

"I think that calculators are fun. I told my parents how fun it is to use a calculators. And on my Birthday i got the Same calculators. I like them very much."

"I liked using them. They were fun to work with. I could make BIG math problems, and small math problems. I could use the calculator in many different ways."

"I feel that for some of us it was a new experience. It encourages a career in mathematics. I think it was a sensible idea."

"Math is not as hard as it was when we did not have calculators & it was fun using theme this year & I we do it next year & next & the next its fun using theme but if you use theme next year why don't you use them all year."

"Our class is using the school calculators. (excuse me: 4x9 = 36 7x9 = 63 9x9 = 81) Soon another class will be Using them. But were having fun with them tell they do. I just can't tell you how much fun were having! (And how much work is esier) Well good-bye tell next time!"

"I have learned a lot with a calculator."

"My fevorite thing to do with the calculator is add up numbers. Calculators are sometimes fun to use. Next year in mathe class I hope that we get to use them again. If I didn't have a calculator I would be sad because I like to a calculator in math. Also I use the calculator to practice my times. It was fun using the calculator in math. At home we have a calculator that I use."

"The calculator helped me to learn negative numbers. Because of the calculator I do better in math. The calculator is a great invention to me."

"Because of the calculator I did much better in math. The calculator helped to me to practice my basic facts. Next year in math class I hope that we will have calculators too."

"I liked playing the calculator game. I didn't like the calculator because sometimes it didn't tell the right answer. It didn't help me very much in math. So the calculator wasn't so bad."

"I liked using calculators. Because I learned a lot of my facks. I did not like the tests all that much."

"I can work better by myself. I hardly ever worked with my calculator. The papers I did with my calculator I got wrong. I cheated 10 times."

"I think it might of helped me alot but I did not use it alot eigther I would not care if we did not have them."

(My favorite thing to do with the calculator is...) "Make problems on it and guess what the answer is, and then see if I'm right." (Because of the calculator I...) "Learned My multupucaion and Divivion tables."

(If I always had a calculator in math class I would...) "do better, but not learn as much as I do now without one." (Because of the calculator I have...) "almost the same grades and it's just the same to think." (Next year in math class I would like to ...) "Do both, but more to figure instead of to mach calculator."

(Next year in math class I would like to...) "Use the calculator agein even if we don't use the calculator agein I will neve forget that I used a calculator in math."

(Next year in math class I would like to ...) "have calculators all year and use them for tests and study hard facts, and play calculator games."

"I thought that we liked them in our classroom and we used them a lot and we made cubby holes for ours. We even did math with them. I don't think the forth graders should use these and be intervuied on the news."

"They helped me in math and in someways it was hard and easy."

"I didn't like using them sometimes I think we shouldn't use them we don't learn anything in may exsept how we use them that I'm not against They were boring close to the end of school we used them on our study sheets and we didn't learn anything The only thing I liked about them was pressing the buttons know I like calculators I don't wish we could have them back, but I like them."

"I think calculators helped me in multiplying becaucaus I was a terrible math person but when we used calculators I improved. So obveusly I like them."

"I think they where ok but it do something wrong, I was adding A whole bunch of numbers and the point came out wrong. but I think I't was a good program."

"I think calculators were kind of hard. Sometimes they were easy. I did honestly like calculators. Just sometimes I had problems. The think I liked was descmals. Even though I had some Problems. The calculator test were fun! I liked calculators."

"I think they were good becaes you lernend most of your faxt's. The games were fun and you lernend how to solve quicker ways to win."

"I thought it was fun but sometimes it was as hard as doing math your self. I feel half and half about calculators. Sometimes I don't like them at all. Though I still like them alot."

"I thought it was fun. I never knew you could do so many things with a calculator. I really liked it. I realy hope we can use them again next year. It realy helped me with my math."

"I thought that using calculators was fun, especially when we did the ditto to see how many dollar bills it would take to get to the sun or the moon. They are the best thing that was in the school at the time. I wish we would never stop using them because I like them."

"I thought that calculators made math better in some ways and bad in other ways. The bad way was that I like to work with my head. But I liked them."

"I thought it was fun, It helped me with my facts I wish we could use it again for a whole year."

"I wish you would burn them all. We didn't learn anything we didn't already know."

"I think they are slow because you have have to punch the numbers in."

"They were realy neat but the batteries to often. Sometimes they didn't help much, but otherwise they were ok."

(Because of the calculator I...) "can do mor things withe my brain I like the calculator moar and moar" (The calculator helped me to...) "Learn my fatchs so I no then by hart."

(Because of the calculator I...) "feel good inside me. and I learned more than I use to know. and I just think they are fun!" (The calculator helped me to...) "Learn my times. and it also helped me to learn my divides. and now that I know all of my times and divides and everything (the teacher) put me into Level II.

"I hate it."

"Superb!"

"I thought it was very fun. I learned new ways to use the calculator. And it made some work much easier."

"I thought they were fun but after a will I didn't think it was that fun."

"I think using calculators saves time and I also think that kids should use calculators and their head."

"It was fun but, I didn't like playing all those dumb games. If we didn't play all those dumb games it would have been better."

"I think it was ok but you didn't have to hardly ever think. But I still had fun using them."

"I thought the calculators were a change in the everyday routine of writing down the problems. I personally liked using them and I would like to use them again next year. But I thought the unit was too short."

"I thought that it was very fun. I like doing math with a calculator. I like doing percentage. I did not like the division part. I use my calculator all the time."

"I think that it helped make a change of pace. It also, I think helped some people memorize multiplication. It made it easyer to go fast in math. I think that 1/3 of each year should be devoted to calculators."

"I thought they were nice to have. It helps you do very hard problems into easy problems. It is very exciting to use. I like it alot."

"I thought it was very nice. I liked to find the answer to times questes. It was good to know you can have fun and learn at the same time."

"It is easy. it is faster than putting on paper. It is fun. Like when you have to decide it takes a pretty long time so the calculators save time for finishing other work."

(Because of the calculator I have...) "more fun in math and get more out of it."

(If i always had a calculator in math class I would...) "probably get tired of it."

(Next year in math I would like to...) "have a calculator sometimes. I don't like calculators because I can't see how they work the problem and I like to see that."

(Because of the calculator I have...) "so far thought of it as a waste of time because of the rare use of it and we really didn't nearly use it to a decent ability, so I am not say it has helped me, though if we knew how to use them, got used to them, and used them on teaching some concepts, I think the calculator would be a help."

(If I always had a calculator in math class I would...) "learn a lot easier. I looked forward to going to math. Then in free time I would have someting to do."

"It was nice on hard problems but it could not help me always when I needed it."

"They wore pretty good. I still like using my brain. It was easier to work though. I like using more advanced calculators better."

"I think they helped me understand what I was supposed to do."

"I think that they made the work faster and easier. The didn't help me learn eany thing. but the help my fingers cordenation."

"I felt like I was CHEATING."

"At first I thought that I wouldn't do any better with calculators, but after we got them I found that I could work faster and that I understood more of what I was doing."

"I think that calculators make math a _ of a lot easier but they sort of help you to understand better its a good experience."

"I thought it was o,k, for kids who don't know how to do math, but to me it was DUMB, and I felt like I was cheating."

"I think it was a Good Idea because in the future Practiclly all math will be done with calculators."

"I think using calculators was fun, and we learned how to use them too. We could grade our work faster. We played games that were fun. But if you use calculators for everything you won't know how to do math. So I think they are good and bad."

"I liked it, it was a good experience, even though I think children could learn better without calculators. I think only older kids, (junior high etc.) should use them." (6th grader now in junior high!)

"I don't like calculators very much because you don't do the work your self, It does it for you. I like doing my math by myself even though I don't understand it sometimes and a calculator doesn't help me any more to understand. (I think we shouldn't use calculators!)"

"I like it. It really made you understand your work more because you had to know what you were doing in order to punch it into the calculator. I liked it in independent math because you got your work done faster and easier but it go confusing on the quizzes because you weren't allowed to use them and you were used to doing with the calculators, then all of the sudden you had to figure it out in your head. But all in all it was fun. They were useful to. Like if you really don't feel like wasting paper space working out problems, just pull out your calculator!"

"I think they are nice and they helped me write my math. I have improved."

"I think that calculators are not worth the money for metal or the money for the Batteries that you use. They sometimes help someone but most of the time they hurt a person Because the people can't learn if the calculator is doing the work."

"It has helped me alot with my work. But sometimes I got kind of confused. I think we should work with them longer."

The children's comments reflect both the variety of their feelings and the feelings of teachers and parents. Of course impressions and feelings are only one aspect of the evaluation.

On the issue of serious harm, the children's comments are mixed. Some felt they learned more. Some felt they learned less. Both the calculator and noncalculator groups showed significant growth on basic facts, mathematics concepts, computations, and applications. There was no evidence of difference between calculator and non-calculator classes.

Children's contention that calculators aided computational performance was also supported by testing. Children performed 2-3 grade levels higher on advanced computational tests when allowed to use calculators. Since the calculator is a quick, efficient computational device the result is not unexpected.

The test data supported the generally positive comments children made about liking calculators. Attitude

towards calculators was very positive throughout the study. By all measures, most children enjoyed using calculators. Observations at all schools suggested children consistently excited about using calculators.

One difficulty raised by children's comments which was unsupported by the data was some children's tendency to feel guilty when using a calculator -- in fact, so guilty that the use was associated with cheating. Certainly such feelings are reinforced to some extent by parents and teachers who think that something must be wrong with such quick, efficient computation. However, the data provide no evidence that such guilt is warranted.

Summary

Widespread concern over the use of calculators by young children prompted a broad, year-long study of the impact of calculators on elementary school mathematics learning. In the context of the level of calculator use elementary teachers are likely to implement in the first year with calculators available for all children and limited supplementary materials for student use, the following conclusions seem warranted:

1. There are no measureable detrimental effects for the first-year use of calculators for teaching mathematics in grades 2-6.
2. Children have a high, positive attitude toward using calculators in mathematics.

3. Children learn to use calculators for computation with 30 minutes of instruction and can perform computations much more successfully than children not using calculators.

Informal observations by site directors and teachers suggest that curriculum implications for calculators in the elementary school could be dramatic. Presumably these results will allow educators to begin developing and testing calculator use methods and activities which have potential benefits to elementary school mathematics. The testing for detrimental effects should not end with this study. Not yet tested are the possible effects of longer (more than 14 weeks) and more intensive calculator use (greater than 30-40%). Such studies would be reasonable follow-ups and serve a public need.

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APPEMDIX A

Pupil Attitude Measures

NAME_____

EXAMPLE: FOR EACH PAIR OF WORDS BELOW PLACE AN X ON THE BLANK THAT BEST TELLS HOW YOU FEEL ABOUT--

SNOW

LIKE _____ : _____ : _____ : _____ : _____ HATE

COLD _____ : _____ : _____ : _____ : _____ HOT

WORK _____ : _____ : _____ : _____ : _____ PLAY

DIRECTIONS: FOR EACH PAIR OF WORDS BELOW PLACE AN X ON THE BLANK THAT BEST TELLS HOW YOU FEEL ABOUT - -

MATH

BAD _____ : _____ : _____ : _____ : _____ GOOD

SAD _____ : _____ : _____ : _____ : _____ HAPPY

BORING _____ : _____ : _____ : _____ : _____ EXCITING

JUMP IN _____ : _____ : _____ : _____ : _____ HOLD BACK

HARD _____ : _____ : _____ : _____ : _____ EASY

MORE _____ : _____ : _____ : _____ : _____ LESS

NAME_____

EXAMPLE: FOR EACH PAIR OF WORDS BELOW PLACE AN X ON THE BLANK THAT BEST TELLS HOW YOU FEEL ABOUT - -

SNOW

LIKE _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ HATE

COLD _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ HOT

WORK _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ PLAY

DIRECTIONS: FOR EACH PAIR OF WORDS BELOW PLACE AN X ON THE BLANK THAT BEST TELLS HOW YOU FEEL ABOUT - -

CALCULATORS

BAD _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ GOOD

SAD _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ HAPPY

BORING _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ EXCITING

JUMP IN _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ HOLD BACK

HARD _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ EASY

MORE _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ : _ _ _ _ LESS

Teacher Attitude Measure

Date:_____ Name_____

Example: For each pair of words below place an X on the blank that best tells how you feel about--

SNOW

like ___: _X_: ___: ___: ___ hate

cold _X_: ___: ___: ___: ___ hot

work ___: _X_: ___: ___: ___ play

These responses would indicate that the person likes snow but is not crazy about it. The person thinks snow is very cold and that snow means some work and some play.

Directions: For each pair of words below place an X on the blank that best tells how your feel about--

MATH

beneficial ___: ___: ___: ___: ___ harmful

passive ___: ___: ___: ___: ___ active

understandable ___: ___: ___: ___: ___ mysterious

frill ___: ___: ___: ___: ___ necessary

deep ___: ___: ___: ___: ___ shallow

bad ___: ___: ___: ___: ___ good

changing ___: ___: ___: ___: ___ constant

tool ___: ___: ___: ___: ___ toy

strange ___: ___: ___: ___: ___ familiar

weak ___: ___: ___: ___: ___ strong

simple ___: ___: ___: ___: ___ conplicated

confining ___: ___: ___: ___: ___ expanding

sad ___: ___: ___: ___: ___ happy

brave ___: ___: ___: ___: ___ scared

slow ___: ___: ___: ___: ___ fast

crutch ___: ___: ___: ___: ___ tool

boring ___: ___: ___: ___: ___ exciting

jump in ___: ___: ___: ___: ___ hold back

hard ___: ___: ___: ___: ___ easy

more ___: ___: ___: ___: ___ less

Date:_____ Name_____

Example: For each pair of words below place an X on the blank that best tells how you feel about--

SNOW

like ___: _X_: ___: ___: ___ hate

cold _X_: ___: ___: ___: ___ hot

work ___: ___: _X_: ___: ___ play

These responses would indicate that the person likes snow but is not crazy about it. The person thinks snow is very cold and that snow means some work and some play.

Directions: For each pair of words below place an X on the blank that best tells how you feel about--

CALCULATORS

beneficial ___: ___: ___: ___: ___ hate

passive ___: ___: ___: ___: ___ active

understandable ___: ___: ___: ___: ___ mysterious

frill ___: ___: ___: ___: ___ necessary

deep ___: ___: ___: ___: ___ shallow

bad ___: ___: ___: ___: ___ good

changing ___: ___: ___: ___: ___ constant

tool ___: ___: ___: ___: ___ toy

strange ___: ___: ___: ___: ___ familiar

weak ___: ___: ___: ___: ___ strong

simple ___: ___: ___: ___: ___ complicated

confining ___: ___: ___: ___: ___ expanding

sad ___: ___: ___: ___: ___ happy

brave ___: ___: ___: ___: ___ scared

slow ___: ___: ___: ___: ___ fast

crutch ___: ___: ___: ___: ___ tool

boring ___: ___: ___: ___: ___ exciting

jump in ___: ___: ___: ___: ___ hold back

hard ___: ___: ___: ___: ___ easy

more ___: ___: ___: ___: ___ less

Basic Facts Tests

NUMBER FACTS

This test consists of four sets of primary number facts to be read to the pupils. Pupils are to write only the answers in the spaces provided. Have numbered lines on the chalkboard to use in teaching the procedure if the pupils are unfamiliar with it. The number facts are read by the teacher at a rate of one every 5-7 seconds. In reading the number facts, use those terms for the arithmetic operations that are familiar to the pupils; for example, 3 + 4 may be read as "3 plus 4" or "3 and 4," 4 - 3 may be read as "4 minus 3," "4 take away 3," "3 from 4," etc. so long as pupils are familiar with the terms.

Pass out the answer sheets.

THEN SAY TO THE PUPILS:

This is a test to find out what you already know about number facts. I will read a number question. You write just the answer. If you do not know an answer quickly, make a short line after the number for that question and be ready for the next question. It is very important that you write the answers in the correct spaces. I will read each question just once.

THEN SAY:

Here is an example. Do <u>not</u> write the answer to the example on your answer sheet. If I say: "Number one, *(pause)*, 2 plus 2" what should you write?

Wait for the class to answer.

That is right, 2 and 2 is 4; 2 plus 2 equals 4.

Write "4" on line one on the chalkboard.

If I say, "Number two, 11 plus 2."

Pause.

Suppose you do not know the answer. What will you do?

Pause.

Yes, draw a short line after number 2.

Illustrate at chalkboard.

Are there any questions about what you are to do?

Use more illustrations if needed. You may make up a short practice test and use it to teach the procedure if you believe it to be desirable.

Part A: ADDITION

THEN SAY:

Find column one. It is labeled Part A: ADDITION.

Hold up an answer sheet and point to the proper place.

I will read the question just once. Keep up with me. Do not worry if you need to skip an answer. Make sure you write your answer in the correct column and beside the number of the question that I read.

1. 1 + 9	11. 6 + 6
2. 4 + 3	12. 8 + 4
3. 0 + 0	13. 7 + 6
4. 8 + 1	14. 9 + 3
5. 5 + 5	15. 6 + 5
6. 2 + 4	16. 7 + 9
7. 3 + 3	17. 4 + 9
8. 5 + 4	18. 7 + 5
9. 4 + 6	19. 5 + 8
10. 7 + 3	20. 9 + 9

When the last number fact has been read, continue with the directions for Part B: MULTIPLICATION or give the pupils a brief rest period, then continue.

Part B: MULTIPLICATION

SAY TO THE PUPILS:

Now look at column two on your answer sheet. It is labeled Part B: MULTIPLICATION. We will do this part just as we did Part A: ADDITION. Are there any questions?

1. 2 x 2	11. 5 x 9
2. 4 x 2	12. 6 x 6
3. 2 x 5	13. 8 x 5
4. 6 x 2	14. 2 x 1
5. 6 x 2	15. 8 x 7
6. 2 x 7	16. 9 x 4
7. 2 x 9	17. 0 x 4
8. 6 x 4	18. 6 x 8
9. 4 x 4	19. 9 x 8
10. 4 x 7	20. 5 x 7

It is suggested that an hour of different work follow the administration of Part B: MULTIPLICATION before proceeding with Part C: SUBTRACTION. If this procedure is used, have the students print their name on the top of their answer sheet, collect the sheets, and redistribute them when Part C: SUBTRACTION is administered.

Part C: SUBTRACTION

Pass out the answer sheets, making sure that each pupil receives his own sheet. THEN SAY TO THE PUPILS:

Do you have your own answer sheet?

THEN SAY:

Find column three. It is labeled Part C: SUBTRACTION. When I read a number question, you write just the answer. If you do not know the answer, draw a short line after the question. Keep up with me. Don't worry if you need to skip an answer. Make sure that you write your answer in the correct column beside the number of the question that I read.

1.	10 - 9	11.	12 - 6
2.	7 - 3	12.	12 - 4
3.	0 - 0	13.	13 - 6
4.	9 - 1	14.	12 - 3
5.	10 - 5	15.	11 - 5
6.	6 - 4	16.	16 - 9
7.	6 - 3	17.	13 - 9
8.	9 - 4	18.	12 - 5
9.	10 - 6	19.	13 - 8
10.	10 - 3	20.	18 - 9

When the last number fact has been read, continue with the directions for Part D: DIVISION, or give the pupils a brief rest period, then continue.

Part D: DIVISION

SAY TO THE PUPILS:

Find column four. It is labeled Part D: DIVISION. We will do this part as we did the other three parts of the test. Are there any questions?

1.	4 ÷ 2	11.	45 ÷ 9
2.	8 ÷ 2	12.	36 ÷ 6
3.	10 ÷ 5	13.	40 ÷ 5
4.	12 ÷ 2	14.	2 ÷ 1
5.	16 ÷ 2	15.	56 ÷ 7
6.	14 ÷ 7	16.	36 ÷ 4
7.	18 ÷ 9	17.	0 ÷ 4
8.	24 ÷ 4	18.	48 ÷ 8
9.	16 ÷ 4	19.	72 ÷ 8
10.	28 ÷ 7	20.	35 ÷ 7

After the last item is completed, collect the answer sheets from the pupils.

Number Facts

Name _____

81

Part A: Addition	*Part B: Multiplication*	*Part C: Subtraction*	*Part D: Division*
1. _____	1. _____	1. _____	1. _____
2. _____	2. _____	2. _____	2. _____
3. _____	3. _____	3. _____	3. _____
4. _____	4. _____	4. _____	4. _____
5. _____	5. _____	5. _____	5. _____
6. _____	6. _____	6. _____	6. _____
7. _____	7. _____	7. _____	7. _____
8. _____	8. _____	8. _____	8. _____
9. _____	9. _____	9. _____	9. _____
10. _____	10. _____	10. _____	10. _____
11. _____	11. _____	11. _____	11. _____
12. _____	12. _____	12. _____	12. _____
13. _____	13. _____	13. _____	13. _____
14. _____	14. _____	14. _____	14. _____
15. _____	15. _____	15. _____	15. _____
16. _____	16. _____	16. _____	16. _____
17. _____	17. _____	17. _____	17.
18. _____	18. _____	18. _____	18. _____
19. _____	19. _____	19. _____	19. _____
20. _____	20. _____	20. _____	20. _____

Estimation Test

ESTIMATION

This test consists of twelve estimation problems to be read to the students. Use the same procedures which were used for the Number Facts tests.

The problems are read by the teacher at a rate of one every 5-7 seconds. In reading the problems, use terms for the arithmetic operations that are most likely to be familiar to the pupils; for example, 3.1 + 4 may be read as "3 point 1 plus 4" or "3 and one tenth plus 4" etc.

Pass out the answer sheets.

THEN SAY TO THE PUPILS:

This is a test to find out what you know about estimating answers to problems. You circle the number which is closest to the right answer. You should not work the problem, just listen and look at the problem and make your best guess.

THEN SAY:

Here is an example. Look at the first problem on your answer sheet marked Sample A. If I say: "Sample A. (pause) 9 plus 9" what number should you circle?

Wait for the class to answer.

That is right, 9 + 9 is about 20 so you should circle the number 20.

Are there any questions about what you are to do?

Turn your paper over and we will begin.

1. 32 + 66	is about	7. 9 + 9.9 + 999	is about
2. 126 - 42	is about	8. 23 - 46	is about
3. 8 x 51	is about	9. 430 ÷ 1.02	is about
4. 208 ÷ 98	is about	10. 7.4 + 4 + 80	is about
5. 42 ÷ .9	is about	11. 5260 - 470	is about
6. 2.1 x 28	is about	12. 1.02 x 12	is about

Print your first and last name in the space at the top of the page.

Collect the papers as soon as the children finish printing their names on them.

SAMPLE A

(Circle One)

A. 9 + 9 2 20 50 200

NAME _____

ESTIMATION

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(Circle One)

1. 32 + 66	50	100	290	3000
2. 126 - 42	8	40	80	160
3. 8 x 51	40	59	131	400
4. 208 ÷ 98	2	20	200	2000
5. 42 ÷ .9	5	36	55	360
6. 2.1 x 28	2.128	30	49	60
7. 9 + 9.9 + 999	10	100	1000	10,000
8. 23 - 46	-20	20	70	-70
9. 430 ÷ 1.02	420	440	4360	43,600
10. 7.4 + 4 + 80	100	150	200	250
11. 5260 - 470	100	500	1000	5000
12. 1.02 x 12	1.14	12	22.02	114

Special Topics Tests

Teacher's Directions
for Administering
Special Topics Test
Grades (2-3)

This test is in two parts:

Part I. Items 1-12 (Pink sheets) without use of calculators

Part II. Items 13-18 (White sheets) with use of calculators

(Before distributing the tests, be sure each student has a calculator.)

Distribute the test booklets and ask the students to write their first and last names on the front. Read and work thru example A, B, and C on the front of the booklet.

The format for items 5-18 is similar to that of the Stanford Test. The major difference is that the student is asked to circle the response. If the student's answer is not among the choices then the student should circle "Not Here". You will be reading the items to the students.

After you are confident that the children understand the directions then administer the test. Remember items 1-12 are to be done without the calculators.

Read the items exactly as they are stated below. Do not read the choices.

Number 1. What would you subtract from 1752 to change the "5" to "0" without changing any of the other digits?

Number 2. Write the number for two thousand four hundred eighty-seven.

Number 3. Write three and five tenths as a decimal.

Number 4. Write the number for negative five.

Number 5. How many hundreds does the above number have?

Number 6. How many tenths does the above number have?

Number 7. Look at the number line. Which number would be at point A?

Number 8. Which number is smaller?

Number 9. Look at the row of numbers, eighty-one, ninety-one, one hundred one, one hundred eleven, blank. Which number would come where the blank is?

Number 10. Which number would you add to 37 to get a number between 70 and 80?

Number 11. The temperature in Kansas City is ten degrees. It is twenty-five degrees colder in Minneapolis. What is the temperature in Minneapolis?

Number 12. Which number is closest to forty-two thousand nine hundred fifty-three?

Ask the children to stop, turn on their calculators and check to be sure they are working properly. After you are confident that all the students have good calculators go on with items 13-18. (Be sure you have some extra calculators and batteries on hand to replace any that go bad during the testing). Read the items exactly as stated below.

Number 13. Larry has 26 Star Wars trading cards. Jason has 32 cards and Mary has 64 cards. They all give their cards to Judy. How many cards does Judy have?

Number 14. John and Mary were both pulling their dogs in wagons. John's dog weighed 17 pounds and Mary's dog weighed 67 pounds. How many pounds should be added to John's wagon so that they both pull the same weight?

Number 15. If seven children share 100 cookies so that each have the same number, how many <u>whole</u> cookies would each child get?

Number 16. If 279 children each brought 7 pennies to school, how many pennies would you have altogether?

Number 17. Mr. Jackson has 1253 cars to load on his boat. Each car weighs 3527 pounds. How many pounds will be added to the boat?

Number 18. Pete went to the grocery store with his mother. She bought the items pictured below. How much did the groceries cost?

After the children have recorded their answers to the last item, collect the papers.

Name _____

CESM

Special Topics
Grades 2-3

SAMPLE

Write the answer to these questions in the space provided.
If you don't know the answer, place a line in the space.

A. $2 + 3 = ?$ A _____

B. The square root of 4 is B _____

Circle the answer to the question.

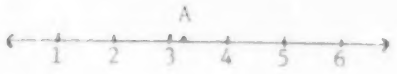
		(Circle One)			
C.	Which number is the smallest?	1	3	5	6

For problem A, we would write 5 in the space provided. For problem B, most of us would draw a line, since we don't know the answer. For problem C, we would circle the 1.

Write the answer to these questions in the space provided.
If you don't know the answer, place a line in the space.

		Answer
1.	What would you subtract from 1752 to change the "5" to "0" without changing any of the other digits?	1. _____
2.	Write the number for two thousand four hundred eighty-seven.	2. _____
3.	Write three and five tenths as a decimal.	3. _____
4.	Write the number for negative five.	4. _____

Circle the answers to these questions.

		(Circle One)				
5.	12459 How many hundreds does the above number have?	2	4	5	8	Not Here
6.	45.78 How many tenths does the above number have?	4	5	9	8	Not Here
7.	 Which number would be at point **A**?	3.2	3	1.3	32	Not Here

(No Calculator)

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(Circle One)

8. Which number is smaller?	-6	-3			
9. 81, 91, 101, 111, _____ Which number would come where the blank is?	12	120	112	211	Not Here
10. Which number would you add to 37 to get a number between 70 and 80?	24	54	44	34	Not Here
11. The temperature in Kansas City is 10°. It is 25° colder in Minneapolis. What is the temperature in Minneapolis?	0°	15°	-25°	-15°	Not Here
12. Which number is closest to 42,953?	42,900	43,000	42,000	4295	

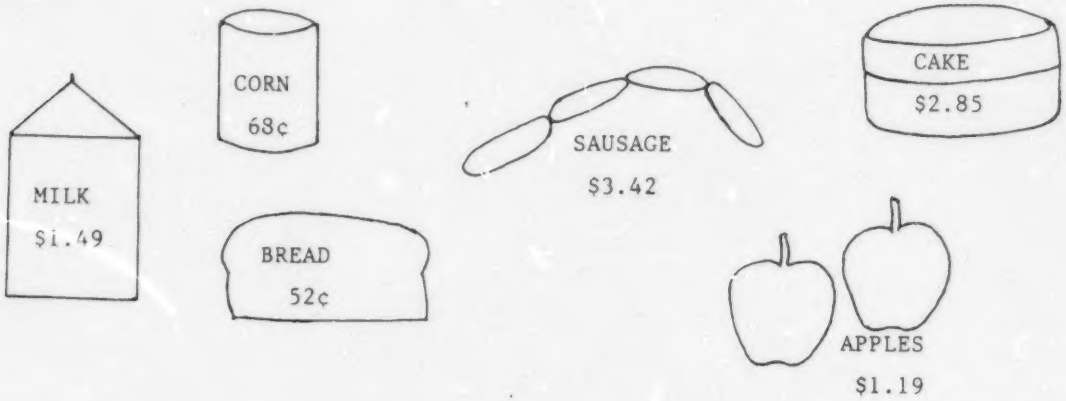
STOP!

(Circle One)

13.	Larry has 26 Star Wars trading cards. Jason has 32 cards and Mary has 64 cards. They all give their cards to Judy. How many cards does Judy have?	100	64	2722	122	Not Here
14.	John and Mary were both pulling their dogs in wagons. John's dog weighed 17 pounds and Mary's dog weighed 62 pounds. How many pounds should be added to John's wagon so that they both pull the same weight?	79	49	45	55	Not Here
15.	If seven children share 100 cookies so that each have the same number, how many <u>whole</u> cookies would each child get?	14	15	93	95	Not Here
16.	If 279 children each brought 7 pennies to school, how many pennies would you have altogether?	272	286	1953	3985	Not Here
17.	Mr. Jackson has 1253 cars to load on his boat. Each car weighs 3527 pounds. How many pounds will be added to the boat?	2274	4780	4,419,331	28,148,443	

(Circle One)

18.	Pete went to the grocery store with his mother. She bought the items pictured below. How much did the groceries cost?	$8.95	$10.15	$128.95	Not Here



Teacher's Directions
for Administering
Special Topics Test
Grades (4-6)

This test is in two parts:

Part I. Items 1-16 (Yellow sheets) without use of calculators

Part II. Items 17-35 (White sheets) with use of calculators

(Before distributing the tests, be sure each student has a calculator.)

Distribute the test booklets and ask the students to write their first and last names on the front. Read and work thru examples A, B, and C on the front of the booklet.

The format for items 17-35 is similar to that of the Stanford Test. The major difference is that the student is asked to circle the response. If the student's answer is not among the choices then the student should circle "Not Here".

After you are confident that the children understand the directions then administer the test. Remember Part I (items 1-16) are to be done without the calculators.

After 15 minutes tell the students to stop, turn on their calculators and check to be sure they are working properly. After you are confident that all the students have good calculators tell them to go on to Part II (17-35). (Be sure you have some extra calculators and batteries on hand to replace any that go bad during the testing.)

After 15 minutes on Part II tell the students to stop.

AW/kmc

Name_____

CESM

Special Topics
Grades 4-6

SAMPLE

Write the answer to these questions in the space provided.
If you don't know the answer, place a line in the space.

A. 2 + 3 = ? A_____

B. The square root of 961 is B_____

Circle the answer to the question.

		(Circle One)			
C.	Which number is the smallest?	1	3	5	6

For problem A, we would write 5 in the space provided. For problem B, most of us would draw a line, since we don't know the answer. For problem C, we would circle the 1.

(No Calculator)

PART I

Write the answer to these questions in the space provided.
If you don't know the answer, place a line in the space.

		Answer
1.	What would you subtract from 1752.63 to change the "3" to "0" without changing any of the other digits?	1. _____
2.	Write the number for eighty-two thousand four hundred seven.	2. _____
3.	Write twenty-six hundreths as a decimal.	3. _____
4.	Write the number for negative five.	4. _____
5.	Write the number for five thousand seven hundred sixty-three and sixty-five thousandths.	5. _____

Circle the answers to these questions.

		(Circle One)				
6.	12459.78 How many hundreds does the above number have?	2	4	5	8	Not Here
7.	3791.62 How many tenths does the above number have?	1	2	7	9	Not Here
8.	Which number is smaller?	-6	-3			

(No Calculator)

(Circle One) 97

9.	Which number is the bigger?	.7	.146			
10.	The temperature in Kansas City is 10°. It is 25° colder in Minneapolis. What is the temperature in Minneapolis?	0°	15°	-25°	-15°	Not Here
11.	Which number is closest to 42953?	42,900	43,000	42,000	4295	
12.	What is 43.7 rounded to the nearest whole number?	44	43	40	50	Not Here

STOP!

Hand in your paper and pick up Part II and a calculator from your teacher.

Name _____ (Calculator)

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PART II

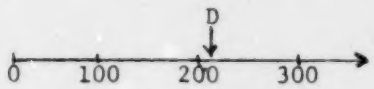
(Circle One)

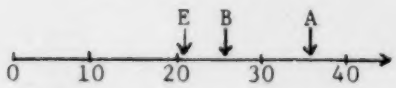
13.	If 279 children in your school each brought 7 pennies to school, how many pennies would you have altogether?	272	286	1954	3985	Not Here
14.	Which number is bigger?	3/7	5/13			
15.	If forty-seven children share 238 cookies so that each have the same number, how many whole cookies would each child get?	5	285	191	11,186	Not Here
16.	The average length of a car in the United States is 18 feet. How many miles long would the line of cars be if 3,000,000 cars were parked bumper to bumper? (1 mile = 5280 feet)	166,666.66 10,227.272		54,000,000 8.7999999		Not Here
17.	The length of a runner's pace is 4 feet. How many paces must he take to run a 26-mile marathon race? (1 mile = 5280 feet)	549,120 104		137,280 34,320		Not Here
18.	Which number would you multiply 21 by to get a number between 820 and 825?	39.5	39	40	39.2	Not Here

(Calcualtor)

(Circle One) 99

19.	Which number would you divide 1643 by to get a number between 14 and 15?	125	95	115	105	Not Here
20.	How many 15s must be subtracted from 210 to get to zero?	10	14	12	16	Not Here
21.	South Dakota has 683,127 people. If each of them gave $3.10 to the Red Cross, how much would that be?	$2.1176937		$2,117,693.70		Not Here
		$220,363.54		$2,203,635.40		





22.	On the number lines above, which letter locates 3.5?	A	B	C	D	E
23.	On the number lines above, which letter locates 20.7?	A	B	C	D	E

Home Calculator Survey

Directions: Read each question and fill in the space below your answer.

1. Is there at least one calculator in your home?

YES ○ NO ○

2. Are you allowed to use a calculator at home?

YES ○ NO ○

3. Do you think you would do better in math if you used a calculator?

YES ○ NO ○ DON'T KNOW ○

4. Do you have a calculator of your own?

YES ○ NO ○

APPENDIX B

Arithmetic Teacher Article

Calculators in Elementary Schools

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This material is based upon research supported by the National Science Foundation under Grant No. SED77-18077. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

With the widespread availability of inexpensive calculators, educators and parents have expressed concern over the effects of calculator use on basic mathematics skills. They want to know the impact calculators will have on learning before they sanction the use of calculators in the classroom. On the other hand, proponents of calculators in schools cite increased motivation and better understanding as potential benefits of calculator use.

During the 1977-78 school year the National Science Foundation funded a project to assess the impact of calculators on the learning of mathematics in the elementary school. Specifically, the question was asked, "Will there be any difference in knowledge of basic facts, computational skill, or understanding as a result of calculator use?" Efforts were also made to assess the motivational effect of calculators.

Design of study

The design specified research sites in Indiana, Iowa, Michigan, Missouri, and Ohio. At a school in each state, two classes at each grade level, 2-6, were randomly assigned to the calculator or no-calculator treatment. (The calculator, no-calculator designation applied to the first semester.) In all, 1500 pupils, 50 teachers and five schools participated in the study.

In early October, 1977 students in the project schools were pretested on mathematics achievement and attitudes. Stanford Achievement Tests were selected for assessing mathematics performance on concepts, computations, and applications. The appropriate grade level battery was administered, (Intermediate or Primary). A Basic Facts test was constructed by randomly selecting 20 facts from each of the four operations, e.g., 8+9, 7×6. A Likert Scale Attitude instrument was developed for measuring attitudes towards mathematics and towards calculators.

In mid October 1977, a two-hour calculator workshop for participating teachers was held at each school. References materials containing recommended calculator activities were made available to teachers of the calculator classes.

Although teachers were encouraged to use calculators to teach concepts, problem solving, and basic facts, the teachers themselves made the decision as to when and how calculators were used in their classrooms. The percentage of time given to calculator use varied greatly from classroom to classroom. Some teachers at each grade level made extensive use of calculators while others made only limited use. On the basis of teacher reports and observations, the use of calculators was estimated to be 30% of class time. A mathematics educator (member of the research team) was present in each school daily throughout the year to observe and instruct with teachers and pupils. Attempts were made to balance the time the mathematics educator was with teachers using calculators in their classes and teachers not using calculators.

In February 1978, fourteen weeks after introduction of calculators into the classes, all pupils were tested (without calculators) on the same topics as before. Additionally, tests were administered to measure estimation skills and performance on certain topics not typically taught at the grade level tested, e.g., addition of integers and decimals.

Following the fourteen week (October-February) period, treatments were reversed; the previous calculator classes no longer used calculators and calculators were made available for the previous no calculator classes. This design was planned as a safe guard so that compensatory activities could be provided if declines were noted in the February testing. Furthermore, from the schools perspective, it was desirable for all pupils in the study to have calculator experience. Since no declines were found in the February testing the March to May period was simply a time of calculator experience for half the sample. In May all pupils were tested on basic facts, computation and attitudes. The May testing was planned to monitor basic skills and attitudes.

Findings

While scores on basic facts, concepts, computations, and applications increased significantly from October to February and predictable grade level differences were observed, there was not a significant difference in the test scores between calculator and no calculator classes.* The means are shown in Tables 1 and 2. The classes that used calculators scored about the same as those not using calculators on each of the attitude and achievement measures. The May testing on attitudes and basic facts, and computations showed no significant differences between treatment groups. For all children, attitudes towards calculators remained high throughout the year and were much more positive than attitudes towards mathematics. Although longer term effects are still unknown, this research found no evidence of a decline in students performance in mathematics resulting from a one-year period of calculator use. In fact, there was some evidence that primary pupils' learning of mathematics is enhanced through calculator use.

Many teachers consider calculators inappropriate for use in the elementary school, particularly in the primary grades (Suydam 1976). In general, the attitude of principals, teachers, and parents is not favorable toward calculator use with young children. This position seems based on the assumption that calculators will "short circuit" the learning of basic facts and mathematical thought. Yet our experiences in fifty elementary school classrooms, grades 2-6, do not support this concern. Children using calculators do continue learning basic facts and mathematical concepts. In this study the children using calculators during the semester scored as well on tests of basic facts and computations as children not using them. On the basis of this evidence there seems to be no support for the "short circuit" theory.

*Persons interested in the statistical analysis procedure should write the authors. A detailed report will be published elsewhere.

Based on this study, the authors are convinced that calculators can have a positive effect on mathematics learning in the elementary school and their use at this level should be encouraged. Calculators are helpful in motivating elementary school pupils to learn mathematics. This statement is based on many comments throughout the year by teachers and pupils as well as attitude test data.

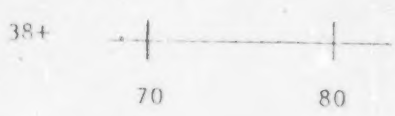
Authors' Observations

Activities that involve the use of calculators in grades 2-6 are easy to implement. For example, by using the constant addend feature of most inexpensive calculators, children can count forwards by any specified number such as ones, twos, fives, or tens. They can also count backwards in a similar manner. By counting by ones to 1000 on a calculator, seeing the display show the number at each step (it takes second graders about six minutes to do this), children get a feeling for the size of 1000. When asked about her progress when she reached 810, one child hesitated and responded, "You mean I just have to go through the 800's and 900's and then I'm there?"

Place value concepts can also be developed naturally with calculators. With 387 entered, a child is asked, "What can you subtract from 387 to give a zero where the 8 is?" Children gain knowledge of "tens place" when they find that 80 and not 8 will produce the desired result.

Children at all grades love to play the estimation game:

What can you add to 38 so the sum is between 70 and 80?



With this activity we have observed children motivated to find all numbers that work. Although this activity can be used without calculators, the immediate feedback possible with calculators allows pupils to focus on strategies and build valuable estimation skills. Similar activities can be used for multiplication, division, subtraction, and made even more challenging by reducing the specified range.

The use of a calculator encourages the exploration of decimals and negative numbers. As children explore the arithmetic functions on a calculator, decimal displays are likely to appear. A number-line model and brief explanation that 3.6 is between 3 and 4 will help young children to become comfortable with decimals. Negative numbers will arise also from time to time (e.g., 6 - 8 = -2). A thermometer can be used to help children grasp the idea of these new numbers quickly. When children have access to calculators, numerous advanced topics in mathematics can be introduced and developed in a meaningful manner.

Teachers must recognize, however, that certain ideas will not be comprehensible to children in the primary grades just because the calculator will perform the computations; there are limits to the cognitive complexity with which young children can cope. Although repeated addition practice on a calculator may assist in conceptualizing multiplication, many different and varied experiences over time provide the basis for understanding the operation of multiplication. It is possible, however, for children to solve multiplication and division word problems prior to gaining proficiency in the computational procedures.

Children soon learn (much to their surprise) that the calculator doesn't think for them. This is understandable since much of their work in the past has been computational and a calculator will do that type of work very well. But mathematics is more than computation. With a calculator to perform computations, pupils can approach concepts and problems at a higher level, focusing on such questions as, What is a prime number? or Under what condition do I divide? One teacher in the project said,

"Some (pupils) would tackle difficult math problems with a calculator, they would not think of trying without it." Pupils comments also reflected this point. Three comments from pupils in the project are: "I have learned alot with a calculator." "I have learned my math better", and "I have been able to understand things better because I would do them until I would get them right."

There are many ways calculators can be used to help children learn mathematics. In this project a variety of instructional strategies were used. For example, calculators can be used to reinforce basic facts, discover new concepts, play instructional games, search for patterns, solve application problems, and teach problem solving.

Although it may seem helpful for children to use calculators to check their work, this is not the best use of calculators; an answer key is cheaper, more accurate, and quicker. Furthermore, answer checking on a calculator encourages children to view paper-and-pencil computation as "right" or "dull" and calculators as "cheating." These attitudes are not appropriate for paper-and-pencil computation or calculators. There may be times when it is appropriate to use calculators to check answers but the overall effect must be considered.

In general, mathematics educators agree that following suitable concept development children should memorize basic addition and multiplication facts. For most children, this requires much practice. One calculator with two children can be an effective tool in practicing facts. A child simultaneously enters a fact e.g., 8×7, in the calculator and presents the fact to a partner who must give the answer before the first child can get the answer on the calculator.

Basic facts can also be practiced using a worksheet like the one shown in Figure 1. A child is instructed to multiply each number in the list by a given number; e.g., in the example in the upper left, each number is multiplied by 3.

Insert FIG. 1 above here

The child enters 3 × 4, does the problem mentally, and then presses =. A check mark is recorded if the answer was correct and an X if incorrect. It is not advisable to have children write their answer in this situation; it could reinforce incorrect responses. We have evidence that this procedure is effective in learning basic facts. The technique is versatile and can be used with any operation and any set of numbers.

Calculators can assist pupils in learning the meaning of concepts such as average. Often this topic is omitted or delayed because children cannot easily handle the computations involved. With calculators, however, the concept of average can be introduced and explored without penalizing the children for any shortcomings in addition division. More attention can be given to uses of averages, how to interpret them, and when an average is an appropriate statistic. Similar arguments apply to many other elementary school mathematics topics that can be studied without children getting bogged down with computation.

Finally, calculators are an excellent aid for developing skill in problem solving, the "sine qua non" of mathematics. With a calculator available to perform the computations, students can focus on choosing the appropriate operations and determining the reasonableness of their solutions. Furthermore, a broader range of strategies are possible. It may be feasible to use trial and error or iterative procedures that would be inefficient without a calculator. Also, the child is not limited to computing with "nice" numbers. Problems involving decimals, noninteger

quotients, and large numbers are more realistic and are more easily processed with the aid of a calculator. Computational skill has no value in itself; it is important only as it is useful in solving problems. Provision for systematic attention to problem solving processes within the classroom would significantly raise the level of mathematics instruction.

Too often, word problems have been viewed as a vehicle for practicing computational techniques when actually algorithms were developed as ways to get answers so that problems could be solved. The use of a calculator gives a better perspective to the purpose of mathematics instruction.

Summary

A study was made of the use of calculators in grades 2 through 6 in one school in each of five different states. The results of that study show no evidence of a decline in mathematics learning in classes that used calculators and there was some evidence that children in the primary grades benefit from using calculators in the study of mathematics. The study also showed that calculators are positive motivators and can be helpful in teaching mathematics. However, it must be noted that long-term (several years) effects of calculator use is not known.

The authors encourage teachers to consider calculators as an instructional aid and to explore ways of using them as an integral part of the teaching/learning process. As more materials for the instructional use of calculators become available, implementation of classroom use of calculators will be facilitated. Some excellent materials are presently available.

A selected reference list of calculator materials can be obtained from the authors.

References

Suydam, M. Electronic Hand Calculators: The Implications for Pre-College Education, Final Report, National Science Foundation, February, 1976.

Figure 1

PRACTICING FACTS

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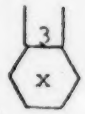
Directions

1. Enter 3 x 4
2. Say your answer.
3. Press = to see calculator's answer.
4. IF you were correct put an ✓. IF wrong put an X.
   (The calculator "remembers" the "3 x ☐".
5. Now press 2
   Say your answer (3 x 2 = ?)
   Press = to see calculator's answer.



4 ____
2 ____
5 ____
8 ____
6 ____
0 ____

5 ____
8 ____
2 ____
4 ____
6 ____
9 ____
0 ____
7 ____
3 ____

2 ____
4 ____
5 ____
7 ____
6 ____
0 ____
9 ____
8 ____
3 ____

6 ____
1 ____
8 ____
5 ____
0 ____
3 ____
7 ____
4 ____

Teacher Notes:

This activity is designed for use with a calculator having a constant multiplier. If the calculator does not have this feature the child enters each fact and names the answer before pressing the = key. Children record ✓'s or X's rather than numbers so that wrong answers will not be reinforced.

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